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THE ABSOLUTE LIMITS OF COLOR SENSITIVITY AND THE EFFECT OF INTENSITY OF LIGHT ON THE APPARENT LIMITS

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INTRODUCTION

In describing a general plan of investigating the chromatic sensitivity of the peripheral retina in an earlier paper (1) the following were mentioned as two of the problems which we wished to take up: (*a*) a point to point determination of comparative sensitivities to the different colors from the center to the periphery, and (*b*) an investigation of the limits of sensitivity. The former of these problems has been made the subject of a recent paper (2). The latter will be treated of here.

The investigation of the limits of sensitivity may be considered from two points of view. As indicated in the first of the papers referred to above, (*a*) it may be made a part of the investigation of the comparative sensitivities of the peripheral retina to the different colors; and (*b*) it may be considered more specifically in relation to points of theory. In the former case the limits should be obtained with stimuli equalized in energy. The results will then represent positions on the retina at which the stimuli for one of the intensities which it is possible to employ have the same or nearly the same threshold value.[1] In the latter case the problem con-

[1] Strictly speaking the threshold value may be considerably less at this point than the intensity of the stimulus employed, because the stimulus may be increased much above the threshold value in the far periphery of the retina without changing the limits by a detectable amount. That is, the stimulus value of the just noticeable

sidered in relation to its historical development divides into two,—a determination of the relative or apparent limits and a determination of the absolute limits. In the second of the papers referred to above it was shown that the determination of the apparent limits was given an undue importance in relation to theory by Hess and his followers because of their failure to realize that great irregularity and not uniformity characterizes the decrease of sensitivity from the center to the periphery of the retina. The details of that demonstration need not be repeated here. The determination of the absolute limits of sensitivity, however, does sustain an important relation to theory, especially to theories of the paired process type; for if it be found that sensation can be aroused farther out from the center of the retina for one of the paired colors than for the other, that fact must tell against the theory unless some supplementary concept is provided to explain the discrepancy. For one thing we have undertaken, therefore, to determine the limits of sensitivity with stimuli any further increase in the intensity of which tends to decrease rather than to increase the chromatic component of the response. For another we have determined the effect of a given range of variation of intensities on the apparent limits. Our reason in part for doing this was to supplement at higher intensities the work of former papers (3) in which we called attention to the large variations that are required in any of the factors influencing the chromatic response (intensity being the most effective of these) to change the limits of sensitivity as much as 1 degree especially when a certain degree of excentricity has been reached, pointing out in particular with regard to the work of previous writers, (*a*) the importance of taking into account deviations of 1–3 degrees from coincidence of limits when conclusions with regard to comparative sensitivities are to be drawn from the results, and (*b*) the futility of making a brightness equalization of the stimuli, with its attendant disadvantages,

difference in limits is much greater than the stimulus value of the difference limen of intensity. In other words, a given point in the peripheral retina may be considered the limit for a range of stimulus intensities, varying in magnitude with its degree of excentricity.

for the determination of the limits with lights of medium and high intensities and perhaps for any but intensities so low as to give very narrow limits. For the latter point three reasons may be given. (1) The brightness equation does not equalize the stimuli in power to arouse the chromatic response, the only subjective equation, so far as we can see, that could rightly be given a place in a determination of the limits of chromatic sensitivity, and this only in a determination of whether or not the same ratio of sensitivity holds for the limits as for the center or other point at which the equation was made. (2) It does not equate them in intensity (the equation is merely of the very selective achromatic response to the stimuli). And (3) so far as the effect of the achromatic on the chromatic component of the excitation is concerned (the final variable that might be considered), it has already been shown by one of the writers in a previous paper (**4**) that there is not enough of this effect for the colors ordinarily used to change the limits by a detectable amount. The particular bearing of the present work on this question is to give a clearer and more definite idea of just how much difference in intensity or equivalent influence is required to change the limits by detectable amounts in the mid and far periphery of the retina. In the beginning this was in fact our chief incentive to undertake the work.

The Problem

The investigation was given the following form. (1) An attempt was made to find out whether by means of our spectroscopic apparatus, which was designed especially to give high intensities of light, stimuli could be obtained which could be sensed as color to the limits of white light vision. (2) The effect on the extension of the limits of sensitivity of varying the stimuli through quite a wide range of intensities was investigated. And (3) the determination of the limits was made in 16 meridians with all of the lights made equal in energy to the blue of the prismatic spectrum employed and with 1/32 of this amount of energy.

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Conditions under which the work was done

The conditions under which the work was done fall under five headings: (1) the wave-lengths of light employed and the means used of getting greater purity of light than is found in the prismatic spectrum; (2) the energy content of the stimuli used and the method of measurement; (3) the control of the brightness of preëxposure and surrounding field; (4) the control of the general illumination of the optics room; and (5) the method of rendering the amount of light entering the eye independent of variations in the size of the pupil, without the use of an artificial pupil. These conditions are so nearly identical with those used in the work of the immediately preceding papers that at the request of the Editor space has not been taken for their repetition in the present paper. For a description of the conditions the reader is referred to 'Chromatic Thresholds of Sensation and their Bearing on Color Theory, Part I.,' this journal, 1919, **26**, pp. 18–25.

The stimulus used was the circular aperture of the campimeter, 15 mm. in diameter, filled with light by the focusing lens. At a distance of 25 cm. from the pupil of the eye, on which the light from the objective slit of the spectroscope was focussed, this aperture subtended a visual angle of 3° 26′. The time of exposure was 1 sec. and the interval between exposures varied between 3–5 min. depending on circumstances and the need for precautionary measures. If the stimulus was sensed in its proper color at any time during the 1 sec. interval of exposure, the retina was called color sensitive at that point. (At the limits of white light vision the red stimulus, for example, of the intensity used was sensed as a tint of red.) The field in the 16 meridians was always mapped for one color before the work on another color was begun.

Systematic results were obtained for all of the points of the work for only one observer. This was the observer whose results were published in the immediately preceding papers: 'Chromatic Thresholds, etc., Parts I. and II.' For data with regard to the various ways in which the normality of both the chromatic and achromatic sensitivity of this observer,

central retina, and chromatic sensitivity, peripheral retina, has been confirmed, the reader is referred to pp. 26–32 of the first of the papers noted above. Data on additional points, important in a general specification of the ocular condition of the observer, have also been published in various places: *e.g.*, on the dioptric or refraction condition and power to sustain acuity in *Trans. Illum. Eng. Soc.*, 1915, 10, p. 1128, and in other papers by us on lighting in relation to the eye; on muscle strength, muscle balance, muscle lag, photopic acuity, near point, range of accommodation, and refraction condition (more recent), *Trans. Amer. Ophthal. Soc.*, 1918, **66**, pp. 142–163; and on scotopic acuity and amount and rapidity of scotopic adaptation, *Trans. Amer. Ophthal. Soc.*, 1919, **67** (in press). The more important points such as the coincidence of the limits of red, yellow and blue with the limits of white light vision; the narrower limits for green; the interlacing of limits for stimuli of medium intensity of equal energy, or of the same general order of intensity; and the large differences in amount of light required to change the limits of sensitivity by a detectable amount in the mid and far peripheral portions of the retina, have been confirmed in a less detailed and systematic way by one or more check observers.

Results

The following results were obtained. (1) It was quite easy to obtain an intensity of light for the red, yellow and blue wave-lengths that could be sensed to the limits of white light vision. In fact these wave-lengths in the spectrum employed were considerably above the threshold at the limits of white light vision in the sixteen meridians investigated. The limits of the green of this spectrum, however, fell far short of the limits for white light; nor could the zone of sensitivity be widened as much as 1 degree by increasing the current in the Nernst filament from 0.6 to 0.8 ampere. The energy entering the eye from the spectrum of the Nernst filament operated by 0.6 ampere of current with the width of collimator slit employed was for the red 9096.639×10^{-10}

watt; for the yellow, 4065.624 x 10^{-10} watt; for the green, 1562.388 x10^{-10} watt; and for the blue, 882.025 x 10^{-10} watt. The energy value of the threshold at the limits of white light vision in the nasal meridian, for example, was for the red 277.836 x 10^{-10} watt; for the yellow, 268.95 x 10^{-10} watt; and for the blue, 264.368 x 10^{-10} watt. The intensity of light for these colors in the 0.6 ampere spectrum was, therefore, strongly supra-liminal at the limits of white light vision, as is stated above. In the 0.6 ampere spectrum, the energy of the green light, it will be noted, was greater than the energy of the blue, but less than the energy of the red and yellow. It was, however, nearly six times as great as the threshold value of these colors at the limits of white light vision. Moreover, when the current was raised to 0.8 ampere this value was considerably increased, but there was still no detectable extension of the limits. Since then the sensitivity to green at the center of the retina and for several degrees towards the periphery is approximately the same as to blue and considerably greater than to red and to yellow, and since so large an increase in the energy value of the stimulus made no detectable difference in the limits and any further increase lessened rather than increased the chromatic component of the response, it seems highly improbable that the limits could by any means whatsoever be extended the 20–35 degrees needed to make them coextensive with the limits of white light vision. It seems fairly certain, therefore, that while the far periphery of the retina is only deficient in its chromatic sensitivity to red, yellow and blue, the blindness to green for the observers used is absolute.

(2) In the investigation of the effect of changes of intensity on the limits of sensitivity eight intensities were used, sustaining to each other the following relations: 1, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64 and 1/128. The highest intensities were taken respectively from the prismatic spectrum of a Nernst filament operated by 0.6 ampere of current and from a spectrum made equal in energy to the blue of this spectrum. These spectra will be designated as Spectrum

A and Spectrum B. The reductions were produced by means of an aluminum sectored disc of 180, 90, 45, etc., degrees open sector. The energy values of the different intensities of light, as has already been stated, were obtained by radiometering the highest intensities and computing the lower from the simple law of the disc. It had been our intention to make the investigation systematically with the eight different intensities in the sixteen meridians of the retina. However, for the purpose of the present paper a briefer substitute plan has been adopted. A preliminary investigation was made with the eight intensities of Spectrum A in two meridians of the retina, the nasal and the temporal, which meridians represent opposite extremes with regard to breadth of zone of sensitivity, in order to get some idea of the amounts of reduction that would be needed to be effective in changing the limits. It was found, for example, that a reduction of the red light to 1/32 of its value at intensity A was not sufficient to narrow the limits in the nasal and temporal meridians, the meridians designated in the tables and charts as 90 degrees. At this value the stimulus was still slightly supra-liminal in these meridians at the limits of white light vision. This amount of reduction, however, was sufficient to narrow the limits for the other stimuli by quite considerable amounts. Also a further investigation showed that it was enough to narrow the limits for red in 12 out of the 16 meridians employed. It was decided, therefore, to make the final determinations in the 16 meridians with the full intensities A and B and with 1/32 A and B. The amount of narrowing for the yellow of the prismatic spectrum in the different meridians produced by this reduction ranged from 3–11 degrees; for the green from 5–17 degrees; for the blue, from 10–18 degrees; and for the red, from 0–8 degrees. For the equal energy spectrum the amount of narrowing for the yellow ranged from 5–18 degrees; for the green, from 5–15 degrees; for the blue, from 4–18 degrees; and for the red from 3–25 degrees.

(3) In case of the equal energy spectrum of the higher intensity, all of the lights with the exception of the green

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were seen in their proper color to the limits of white light vision in each of the 16 meridians. Made equal in energy to the blue of the prismatic spectrum (882.025×10^{-10} watt) the red and yellow were considerably less in energy value than was the green of the prismatic spectrum, still the red and yellow were sensed to the limits of white light vision while the green which represented a considerably greater amount of energy fell short of those limits by amounts varying from 20–35 degrees in the different meridians. There can be no reasonable doubt, we believe, that the difference found here represents an actual difference in sensitivity. It obviously can not be attributed to the relative intensities of the stimuli employed.

Landolt has also investigated the effect of high intensities on the extension of the limits of sensitivity. Writing of this work (**5**), he says: "In ein absolut dunkles Zimmer fiel nur durch eine kleine Öffnung im Finsterladen directes Sonnenlicht. Dieses wurde auf das äusserste Ende des Perimeterbogens gelenkt. Während wir unser Auge ins Centrum des Bogens setzen, bracht man in die kleine, intensive beleuchtete Stelle farbige Papiere von möglichster Intensität der Färbung. Nun bewegtet sich das Auge langsam vom entgegengesetzen Ende des Bogens nach Scheitelpunkte zu und es zeigte sich dabei, dass wenigstens mit der innern Netzhautpartie alle Farben schon bei 90° erkannt wurden. Die Grösse des Objectes betrug weniger als 1 cm^2.

"Als dieselben Prüfungen auch mit Spectralfarben zu machen, entwarfen wir ein Sonnenspectrum im sonst dunkeln Zimmer und liessen es durch eine achromatische Linse auf einen Ende des Perimeters befindlichen Schirm fallen. Dieser hatte eine verändliche Spalte, mittelst welcher man die einzelnen Farben aus dem Spectrum isolieren konnte. Während wir nun wiederum nach langer Adaptation, und bei verbundenem zweiten Auge das eine Ende des Bogens fixierten, würde von einem Assistenten irgendeine Farbe des Spectrums auf die Spalte gelenkt, und wir drehten nun, unter stehter Fixation unserer Fingerspitze, welche sich auf dem Bogen bewegte, das Auge allmählig der Farbe entgegen.

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Es zeigte sich auch hier wiederum dass alle Farbe schon bei 90° erkannt werden, wenn sie intensiv genug sind."

Landolt's investigation was made, it will be noted, in a dark room while ours was made in a light room. We have

TABLE I

A. THE EFFECT OF INTENSITY OF STIMULUS ON THE LIMITS OF SENSITIVITY, PRISMATIC SPECTRUM

In this table are given the results of a preliminary investigation in two representative meridians to show how much reduction is needed to produce a significant change in the limits of sensitivity. Eight intensities of stimulus were used: A, 1/2A, 1/4A, 1/8A, etc.

Meridian Investigated	Stimulus	Limits of Sensitivity for							
		Intensity A	Intensity $\frac{1}{2}$A	Intensity $\frac{1}{4}$A	Intensity $\frac{1}{8}$A	Intensity $\frac{1}{16}$A	Intensity $\frac{1}{32}$A	Intensity $\frac{1}{64}$A	Intensity $\frac{1}{128}$A
Nasal.....	Red (670 μμ)	92	92	92	92	92	92	88	86
	Yellow (581 μμ)	92	92	92	92	91	89	88	88
	Green (522 μμ)	69	69	69	66	63	62	59	56
	Blue (468 μμ)	92	92	87	83	79	78	77	76
Temporal.....	Red (670 μμ)	61	61	61	61	61	61	46	44
	Yellow (581 μμ)	61	61	61	61	55	47	46	45
	Green (522 μμ)	45	45	45	42	34.5	32.5	30	29
	Blue (468 μμ)	61	61	56	45	43.5	43	43	43

B. THE ENERGY VALUES OF THE STIMULI USED

Total energy of light at campimeter opening and at eye

(watt × 10^{-10})

Intensity	Red (670μμ)	Yellow (581μμ)	Green (522μμ)	Blue (468μμ)
A[1]	9096.639	4065.624	1562.388	882.025

[1] The energy values of 1/2, 1/4, 1/8, 1/16, 1/32, 1/64 and 1/128 A may be obtained by dividing the above values by the appropriate factor.

The energy density at the campimeter opening (watt per sq. mm.) may be obtained by multiplying the above values by 0.005659; the energy density at the eye, by multiplying them by 0.303.

not as yet had opportunity to repeat the work of the present paper with the dark adapted eye. However, determinations somewhat rougher and less detailed than those described

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here have sufficed to show that for our observers the far periphery of the retina is color-blind to green also with the dark adapted eye. With reference to the relative insensitivity of the peripheral retina to green, it may further be noted that in our results with the Hering papers with a different set of observers the limits for green fell much nearer to the center of the retina than for red, yellow and blue. The results represented in Fig. 5, for example, were taken from this series of observations. That the limits for green are narrower than for red, yellow and blue with stimuli of the same order of intensity has, moreover, been verified many times in the work of our undergraduate laboratory.

In Table I., A, are given the results of the preliminary investigation in the nasal and temporal meridians to find out whether an intensity of light may not be gotten sufficiently high to make the limits of color sensitivity coincide with the limits of white light vision, and once this intensity is attained how much reduction is needed to produce a significant narrowing of the limits. We have already indicated in this and in previous papers the large changes of intensity that are needed to change the limits by a significant amount when a certain degree of excentricity has been reached. How very large these changes have to be for the far periphery of the retina is shown in this table.

In Table I., B, is given a specification of the energy values of the stimuli used in making the determinations represented in Table I., A. Four energy values may perhaps be considered of importance for each determination: The total value at the campimeter opening, the density per sq. mm. at the campimeter opening, the total energy entering the eye, and the density per sq. mm. at the eye. For the sake of brevity, however, only one of these values is given in the table, namely, the total energy entering the eye; and the factors needed to convert this value into density at the eye and at the campimeter opening are appended in a footnote. Since all of the light from the campimeter opening is focused into the image on the pupil, the figures expressing the total energy at the eye and at the campimeter opening are the same.

The most important of the four specifications noted are probably the total amount of light entering the eye and the density at the campimeter opening. The latter value, for example, sustains a fixed but unknown ratio to the density of the image formed on the retina.

TABLE II

THE BRIGHTNESS VALUES OF PREËXPOSURE AND SURROUNDING FIELD

In this table are given the brightness values of preëxposure and campimeter screen in candlepower per square inch[1] for the determination of limits given in Table I. In all cases in which it was possible the brightness of the preëxposure and campimeter screen was made equal to that of the stimulus at the limits of sensitivity.

Meridian	Stimulus	Brightness Value of Preëxposure and Campimeter Screen for							
		Intensity A	Intensity $\frac{1}{2}$A	Intensity $\frac{1}{4}$A	Intensity $\frac{1}{8}$A	Intensity $\frac{1}{16}$A	Intensity $\frac{1}{32}$A	Intensity $\frac{1}{64}$ A	Intensity $\frac{1}{128}$ A
Nasal....	Red (670 μμ)	0.05088	0.05088	0.05088	0.05088	0.05088	0.05088	0.03093	0.02116
	Yellow (581 μμ)	0.05088	0.05088	0.05088	0.05088	0.05088	0.05088	0.03663	0.02686
	Green (522 μμ)	0.05088	0.05088	0.05088	0.03663	0.03663	0.02686	0.02116	0.01384
	Blue (468 μμ)	0.05088	0.05088	0.03663	0.02686	0.01262	0.01140	0.00643	0.00578
Temporal	Red (670 μμ)	0.05088	0.05088	0.05088	0.05088	0.05088	0.05088	0.03093	0.01791
	Yellow (581 μμ)	0.05088	0.05088	0.05088	0.05088	0.05088	0.05088	0.02686	0.02116
	Green (522 μμ)	0.05088	0.05088	0.05088	0.03663	0.02686	0.01384	0.01140	0.01140
	Blue (468 μμ)	0.05088	0.05088	0.03663	0.03093	0.01262	0.01140	0.00716	0.00643

In Table II. are given the brightness values of the preëxposure and campimeter screen for the work represented in Table I. As stated earlier in the paper the preëxposure and the campimeter screen were selected from the Hering series of standard papers. In case of the higher intensities of light used, No. I of this series (the standard white, coefficient of reflection about 75 per cent.) reflecting the light of the room was not as bright as the stimulus light. These cases may be identified in this and the following tables by the brightness value of this paper under the illumination of the room, namely, 0.05088 cp. per sq. in.

[1] The above values may be converted into millilamberts by multiplying by 486.8.

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In Table III. are given the limits of sensitivity in 16 meridians of the retina for the highest intensity of light used for the work of Table I., intensity A, and for 1/32 A, an intensity representing the order of reduction needed for all of the colors to produce any considerable narrowing of the

TABLE III

THE EFFECT OF INTENSITY OF STIMULUS ON THE LIMITS OF SENSITIVITY, PRISMATIC SPECTRUM

In this table are given the limits of sensitivity in 16 meridians of the retina for intensity A and 1/32A of Table II. The upper vertical meridian is numbered 0° and the lower vertical 180°. Reading down to right or left they are 25°, 45°, 70°, 90°, 110°, 135°, 155°, and 180°.

Meridian Investigated		Limits of Sensitivity for							
		Intensity A				Intensity $\frac{1}{32}$A			
		Red (670μμ)	Yellow (581μμ)	Green (522μμ)	Blue (468μμ)	Red (670μμ)	Yellow (581μμ)	Green (522μμ)	Blue (468μμ)
	0°	65	65	36	65	64	57	29	50
Nasal	25°	86	86	49	86	83	79	36	72
	45°	90	90	52	90	89	83	38	76
	70°	92	92	67	92	92	86	59	77
	90°	92	92	69	92	92	89	62	78
	110°	91	91	68	91	90	87	59	78
	135°	88	88	61	88	87	84	49	75
	155°	86	86	47	86	84	78	35	67
	180°	57	57	36	57	53	47	27	42
Temporal	25°	65	65	44	65	64	55	31	52
	45°	65	65	50	65	57	56	33	51
	70°	62	62	46	62	55	50	35	44
	90°	61	61	45	61	61	47	32.5	43
	110°	58	58	37	58	57	49	31	48
	135°	55	55	32	55	55	48	27	20
	155°	54	54	30	64	50	43	25	41

limits at the extreme periphery of the retina. The 16 meridians used are designated as follows. The upper vertical meridian is marked 0 and the lower vertical 180 degrees. Beginning with 0 and reading down to left or right they are 0, 25, 45, 75, 90, 110, 135 and 180 degrees. The specification of the energy of the stimuli at intensity A and 1/32 A is given, it will be noted, in Table I., B. For all of the stimuli at intensity A, No. 1 of the Hering series of papers was used as preëxposure and campimeter screen, as has already been noted. This paper illuminated by the light of the room was too dark (0.05088 cp. per sq. in.) for all of the four colors at the

limits of sensitivity. However, for the want of a suitable pigment surface of higher reflection coefficient it was used. For intensity 1/32 A, it was darker than the yellow stimulus

TABLE IV

A. THE EFFECT OF INTENSITY OF STIMULUS ON THE LIMITS OF SENSITIVITY, EQUAL ENERGY SPECTRUM

In this table are given the limits of sensitivity in 16 meridians of the retina for stimuli all made approximately equal in energy to the blue of the prismatic spectrum used in Table I., and for 1/32 of this intensity,—intensity B and 1/32 B.

Meridian Investigated		Limits of Sensitivity for							
		Intensity B				Intensity $\frac{1}{32}$B			
		Red (670μμ)	Yellow (581μμ)	Green (522μμ)	Blue (468μμ)	Red (670μμ)	Yellow (581μμ)	Green (522μμ)	Blue (468μμ)
	0°	65	65	34	65	62	56	29	50
Nasal	25°	86	86	47	86	74	70	34	72
	45°	90	90	50	90	74	78	36	76
	70°	92	92	63	92	78	85	50	77
	90°	92	92	69	92	81	87	59	78
	110°	91	91	64	91	79	85	58	78
	135°	88	88	44	88	74	80	42	75
	155°	86	86	36	86	61	74	32	67
	180°	57	57	31	57	46	39	25	42
Temporal	25°	65	65	39	65	57	54	30	52
	45°	65	65	39	65	47	55	32	51
	70°	62	62	42	62	46	48	30	44
	90°	61	61	41	61	40	45	30	43
	110°	58	58	36	58	45	45	29	48
	135°	55	55	28	55	49	41	25	40
	155°	54	54	26	54	47	38	24	41

B. THE ENERGY VALUES OF THE STIMULI USED.

Total energy of light at campimeter and at eye (watt × 10^{-10})

Intensity	Red (670 μμ)	Yellow (581 μμ)	Green (522 μμ)	Blue (468 μμ)
B[1]	891.050	882.510	884.946	882.025

and approximately equal to the green and red. For the blue stimulus Nos. 9–14 of the Hering series (0.01404–0.0114 cp. per sq. in.) were used as needed in the different meridians. The photometric values for these intensities and intensity

[1] The energy value of 1/32 B may be obtained by dividing the above values by the appropriate factor.

The energy density at the campimeter opening (watt per sq. mm.) may be obtained by multiplying the above values by 0.005659; the energy density at the eye, by multiplying them by 0.303.

B and 1/32 B have not been given in detailed tabular form because of the large number of repetitions that occur.

In Table IV., A, are given the limits of sensitivity in 16 meridians of the retina for the four stimuli all made equal in energy to the blue used in Table I. and for 1/32 of this value. These values are, as we have already indicated, designated in

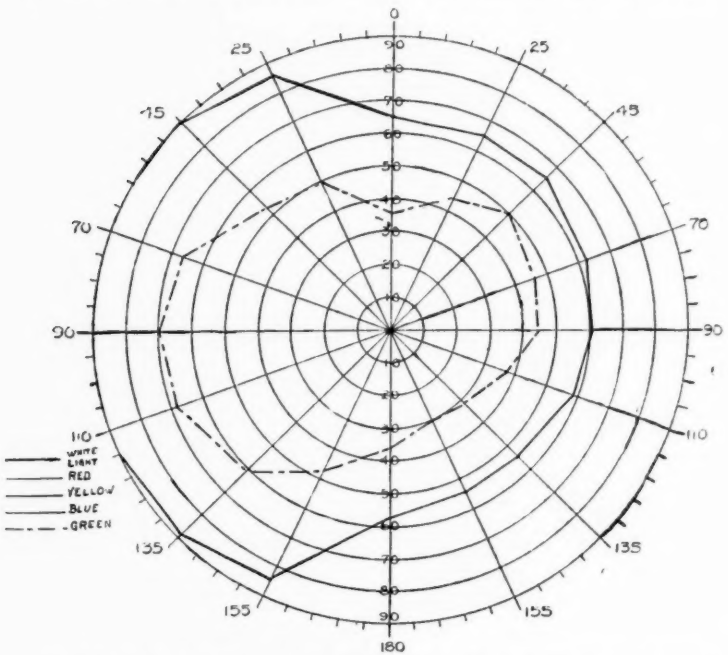

FIG. 1. The effect of intensity of stimulus on the limits of sensitivity, prismatic spectrum. In this chart are represented the limits of sensitivity for intensity A of Table I.: red 9096.639, yellow 4065.624, green 1562.388, and blue 882.025 watt $\times 10^{-10}$.

the table as intensity B and 1/32 B. In Table IV., B, are given the energy values of the stimuli used for Table IV., A. For the higher intensity of these stimuli, intensity B, No. 1 of the Hering series of papers (0.05088 cp. per sq. in.) was used for the preëxposure and campimeter screen. Again it was darker than all of the four colors at the limits of sensitivity. For intensity 1/32 B it was slightly darker than the yellow.

For the green of this intensity the no. 2 gray of this series was used (0.0366 cp. per sq. in.); for the red nos. 10–14 (0.01384–0.0114 cp. per sq. in.) varying for the different meridians; and for the blue, nos. 7–14 (0.01791–0.0114 cp. per sq. in.).

A graphic representation of the results of Table III. is given in Figs. 1 and 2. In Fig. 1 are shown the limits of

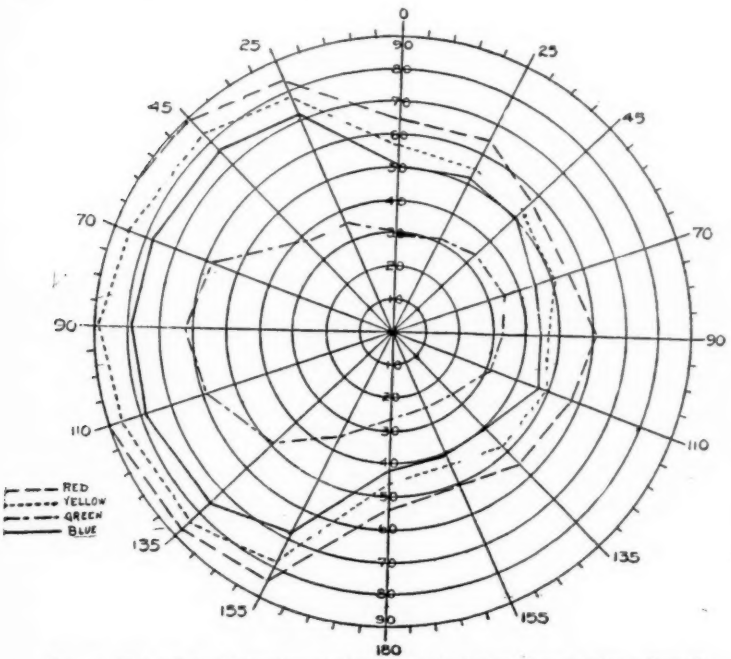

FIG. 2. The effect of intensity of stimulus on the limits of sensitivity, prismatic spectrum. In this chart are represented the limits of sensitivity for intensity 1/32 A of Table I.: red 284.27, yellow 127.051, green 48.825, and blue 27.563 watt $\times 10^{-10}$

sensitivity to the four stimuli in the 16 meridians for the intensities represented in the prismatic spectrum *A*. The limits for the red, yellow and blue stimuli at this intensity are, it will be remembered, coincident with the limits of white light vision. All four limits may be represented, therefore, by a single tracing, an unbroken line in black. The limits for green are represented by a broken line. In Fig. 2 are

represented the limits of sensitivity for the four stimuli at the intensities represented in the prismatic spectrum, 1/32 A. In this case the zone of sensitivity to blue is outlined by an unbroken line and the zones for the other colors by broken lines as indicated in the figure. An inspection of this figure will show that the degree of excentricity of the limits is in the order of the intensity of the stimuli. In discussing the

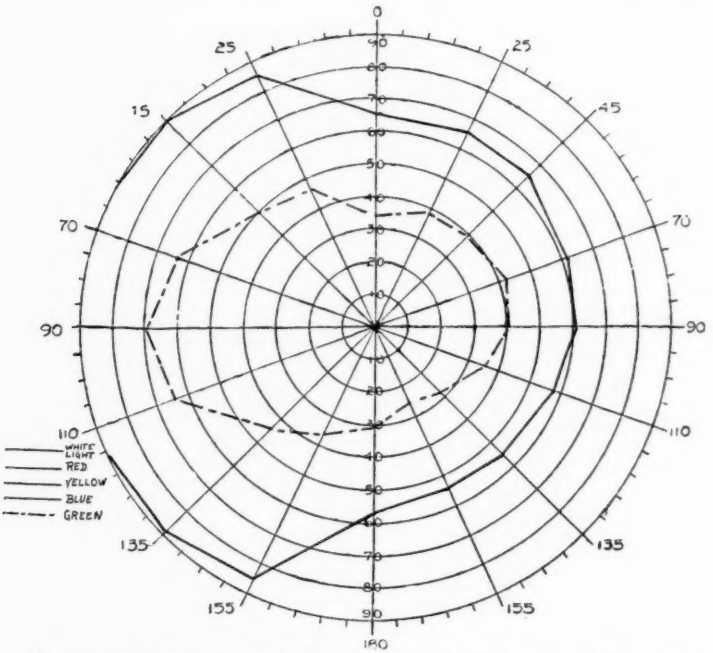

FIG. 3. The effect of intensity of stimulus on the limits of sensitivity, equal energy spectrum. In this chart are represented the limits of sensitivity for intensity B of Table IV.: red 891.05, yellow 882.51, green 884.946 and blue 882.025 watt $\times 10^{-10}$.

significance of the crisscrossing or interlacing of the limits obtained with the Hering pigment papers in previous work, this is what was pointed out would occur if there were a significant difference in the intensity of the stimuli. That is, if the zone of sensitivity to red, for example, is in one meridian wider and in another narrower than to green, etc., it can not

be due to any difference in the intensity of the stimuli; for such a difference, if significant, would make one zone consistently wider or narrower than the other in all meridians.

A graphic representation of the results of Table IV. is given in Figs. 3 and 4. In Fig. 3 are shown the limits of sensitivity to the four stimuli in the 16 meridians for the intensities represented in the equal energy spectrum *B*.

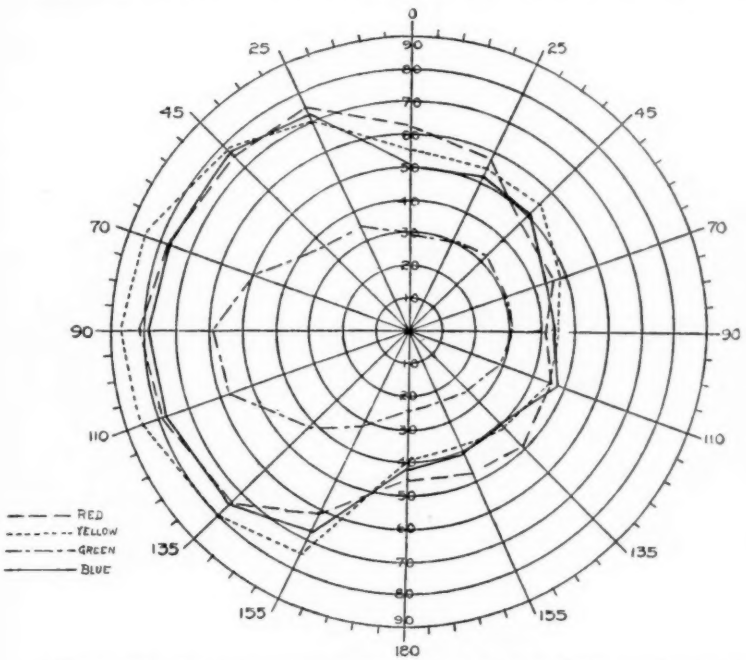

FIG. 4. The effect of intensity of stimulus on the limits of sensitivity, equal energy spectrum. In this table are represented the limits of sensitivity for intensity 1/32 B of Table IV.: red 27.845, yellow 27.578, green 27.655, and blue 27.563 watt $\times 10^{-10}$.

Again the limits for the red, yellow and blue stimuli coincide with the limits of white light vision and are represented by a single tracing, the unbroken line in black. The limits for green are represented by a broken line. In Fig. 4 are shown the limits for the four stimuli at the intensities represented in the equal energy spectrum 1/32 B. With regard to this

figure the following points may be noted. (1) With stimuli of equal energy the limits of no one of the colors, red, yellow and blue, are consistently wider than the others. That is, their limits are characterized by frequent crisscrossing or interlacing. The limits for all three colors, however, are consistently wider than for green. And (2) Fig. 4 sustains a

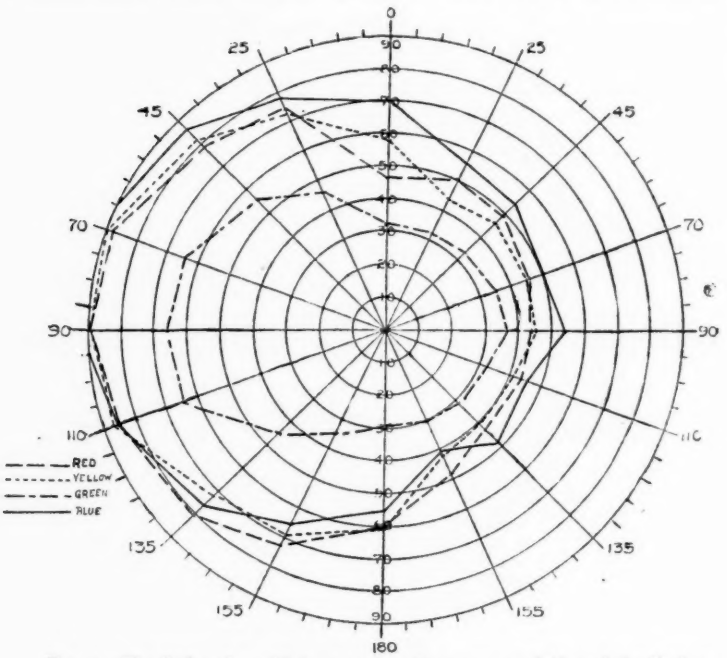

FIG. 5. The limits of sensitivity to red, yellow, green and blue of the Hering series of pigment papers, intensity of illumination, vertical component, 390 foot-candles.

somewhat striking general similarity to the charts obtained for the Hering pigment papers. One of these showing the limits with a surrounding field and preëxposure of the brightness of the colors employed is given in Fig. 5. While no conclusion can be drawn from this similarity with regard to the relative energies of the wave-lengths dominantly reflected by these papers; still it suggests that they may all, roughly speaking, be somewhere near the same order of value, at

least much more nearly so than are these colors in the prismatic spectrum. The red, yellow, green and blue of the prismatic spectrum gave, it will be remembered, rather widely concentric, not crisscrossing limits.

In this general connection it may be of interest also to note the close correlation which obtains between the results of this investigation and those of the previous investigation of the sensitivity of the peripheral retina by the threshold method. That is, wherever the thresholds are found to be low the limits are found to be wide, and conversely wherever the thresholds are high the limits are found to be correspondingly narrow. Some interesting results follow from this. For example, in a given meridian the threshold curve for a given color is found to be very irregular, rising in some places slowly, in others quickly, and still in others dropping and rising again. These fluctuations in the curve are, moreover, different in the different meridians. This means, of course, that the shape of the zones of sensitivity for this color should change with the intensity of the stimulus employed, which is found to be the case. Furthermore, in the same meridian the threshold curves for the different colors differ from each other widely in the direction and amount of the irregularity: and this difference in turn varies from meridian to meridian. The result of this is that a crisscrossing or interlacing of limits must take place whenever stimuli of such relative intensities are used that the limits are of the same general order of excentricity. In other words, as was pointed out in our discussion of this phenomenon in earlier papers, crisscrossing can mean only that there is a lack of uniformity in the relative sensitivity to the different colors in the different meridians. For example, when it occurs in the limits for blue and yellow, it indicates that the ratio of sensitivity to blue and yellow changes in passing from meridian to meridian. In short any investigation at all comprehensive either of the thresholds or limits of sensitivity shows that striking irregularity and not uniformity characterizes the distribution of chromatic sensitivity in the peripheral retina. This is in direct opposition, it will be remembered, to the

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claim made by Hess (**6**) that constancy of ratio of sensitivity to the paired colors prevails throughout the retina which claim, it will be remembered, was advanced by Hering (**7**) in support of his own theory and in refutation of Fick's (**8**) and Leber's (**9**) modifications of the Helmholtz theory to explain the color blindness of the peripheral retina. So far as we are able to determine no one intensity or set of conditions will give coincidence of limits in all meridians for any two colors inside the limits of white light vision.

In conclusion it may not be out of place to point out the bearing of these results on the work of the clinic. In the practice of perimetry as applied to diagnosis it is commonly accepted that the field of vision for the normal eye may be divided concentrically from periphery to center in the following order: white light and form, blue, red and green. It is obvious from the fore-going results (*a*) with stimuli taken from the prismatic and equal energy spectra and (*b*) from the effects obtained by varying the intensity of the stimuli that the responsibility for such a rating of the color fields rests for the greater part with the relative intensities of the pigment stimuli used in the work of the clinic. That is, the limits of sensitivity to red, yellow, blue and white light for stimuli of high intensities are coincident; for stimuli of lower intensities taken from the prismatic spectrum they are rather widely concentric; and for stimuli of equal energies of the order of intensity of 27.563×10^{-10} watt they are interlacing.

Another feature of interest is the claim that has been made by certain clinicians, but not generally accepted, we believe, that the interlacing of the limits for blue and red indicates a pathological disturbance in the relative distribution of sensitivities. While we are not disposed to dispute this conclusion because of a too meager knowledge of all of the data that should be taken into consideration in its evaluation, still we do think it fair to note that pathological disturbances are only one set of factors that may contribute to such a result and that widely different results may be gotten with the same eye with no greater differences in the test conditions than may occur from time to time in the same

clinic or laboratory unless a clear understanding is had of the factors which affect the apparent powers of response of the peripheral retina and adequate means are exercised for their control. These factors are, so far as we are able to list them, composition, area, intensity of the stimulus and duration of the stimulation, breadth of pupil, the intensity of the general illumination and the state of adaptation of the retina, and the brightness of the preëxposure and surrounding field. Obviously if the determination of the apparent limits is to be given clinical significance the work should be done under conditions of work which have been most carefully standardized, for the apparent limits are a resultant of these conditions as well as of the actual distribution of sensitivities.

The degree of importance that is attributed by at least one clinician to the absolute and relative distribution of sensitivities over the retina may be indicated by the following quotation from a recent work on perimetry. "Contraction of the form fields shows the degree of disease of the visual tract. It is better evidence of the real condition of the visual path than an ophthalmoscopic study can possibly furnish. The evidence is minute and analytical. The color fields and color changes moreover furnish a more delicate test in the early stages of the disease and at times furnish a clue to the seat of the trouble before an appreciable change has taken place in the form field" (**10**).

Summary of Results and Conclusions

The more significant features of the above results may be summarized briefly as follows:

1. The far periphery of the retina is not blind to red, blue and yellow. It is merely deficient in sensitivity to these colors. That is, with stimuli of sufficient intensity the limits of red, blue and yellow coincide with the limits of white light vision. The blindness to green, however, is for our observers absolute.

2. The amount of change of intensity required to produce a detectable change in the apparent limits of sensitivity in the more remote parts of the retina is very great. This

amount changes very irregularly from center to periphery of the retina in a given meridian and from meridian to meridian as might be expected from the great irregularity in the distribution of sensitivity in the peripheral retina. (Cf. 'Chromatic Thresholds of Sensitivity from Center to Periphery of the Retina and their Bearing on Color Theory,' PSYCHOL. REV., 1919, **26**, pp. 16–42.)

3. Two other important phenomena may also be mentioned as a result of this irregularity. (*a*) The shape of the zone of sensitivity to a given color changes with the intensity of the stimulus employed in making the determination. And (*b*) when stimuli of equal or of the same order of intensity are used the limits for red, yellow and blue are found to interlace or crisscross each other irregularly rather than to coincide in complementary pairs as was reported by Hegg, Hess and Baird in a more limited investigation of the retina's powers of response. The former phenomenon is the direct corollary of the difference in the rate of decrease of sensitivity to a given color in passing from the center to the periphery of the retina in the different meridians; the latter, to the change in the ratio of sensitivity to the different colors from meridian to meridian. The lack of uniformity of grading of function from point to point in the periphery of the retina, reported in this and previous papers, while striking, can scarcely be considered as surprising. It is in fact just what might be expected of those parts of a sense organ which are little used and poorly developed.

4. The responsibility of the accepted clinic rating of limits in the order from widest to narrowest of blue, red and green doubtless for the greater part rests with the relative intensities of the pigment stimuli used in the work of the clinic. With stimuli of high intensity the limits for red, yellow and blue coincide with the limits of white light vision; for stimuli of lower intensities, taken from the prismatic spectrum, they are rather widely concentric; and for stimuli of equal energies of medium intensities they are interlacing.

5. The interlacing of limits for red and blue is a normal result for stimuli of equal energy of medium intensities. It

may not therefore be due to pathological disturbances in the distribution of sensitivities as has been claimed by certain clinicians. In all responsible work on the determination of the apparent limits it is obviously of great importance to bear in mind that the results are dependent both upon the actual distribution of sensitivity and the numerous factors which affect the apparent powers of response of the peripheral retina.

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SOME FACTORS IN THE PERCEPTION OF RELATIVE MOTION. A PRELIMINARY EXPERIMENT

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The perception of motion is relative. The observer perceives the motion of one object in relation to some stationary object or set of conditions. In the perception of motion an appreciation of the stability of the one object is just as essential and important as the appreciation of the motility of the moving object. The observer himself constitutes the center of reference in most perceptual acts.

The perception of motion involves two aspects, an appreciation of the fact of motion, and an appreciation as to which of the two objects is stationary and which is in motion. These two aspects are to some extent independent variables. One's appreciation of them may be based upon entirely different sets of conditions. One may correctly perceive the fact of motion, but judge erroneously as to which of the two is moving. If a fixated visual object is moved toward an observer, there results a change in the sensory conditions which mediate his judgment of distance. But exactly the same changes will be induced by a movement of the observer toward the object. Changes of these distance criteria as intensity, size of retinal image, accommodation and convergence, etc., serve to induce in both cases an appreciation of a change of the distance between the object and the observer,—an appreciation of the fact of motion. But these sensory changes give no clue as to which object moved and which was stationary. Judgments of the relative motility of the object and the observer depend upon other factors, presumably certain characteristics of either one or both of the two objects concerned.

When the organism constitutes one of the objects in the

perceptual situation, the judgments concerning the motility-stability relation are based in part upon certain sensory aspects of the observer. The nature of these organic stimuli has been pretty well determined. The judgments of relative motion are based upon the presence or absence of such factors as the intention or expectation of moving, the sight or feeling of muscular activity, friction, air currents, the static sense, organic sensitivity, etc. As a rule these factors mediate correct judgments, but exceptions occur as in the illusions of the haunted swing, moving trains, etc. But these organic factors do not constitute the whole of the conditions which influence the judgments of relative motion. These judgments are also based in part upon certain characteristics of the observed object. The haunted swing illusion is probably due in part to the fact that one does not, on the basis of past experience, expect buildings to undergo rotary motion. Likewise the perceptual situation is frequently confined to two observed objects when all spatial relation to the perceiving organism is pretty well excluded. The cloud and moon illusion illustrates such a perceptual situation. It is extremely improbable that this illusion is due primarily or mainly to any erroneous judgment as to the spatial relation of the observer to either of the objects. Rather it seems that the judgment of relative motion in this case depends upon certain peculiarities of the objective situation.

The existence and nature of these objective factors have never been adequately considered. It was the purpose of this experiment to attempt a preliminary investigation concerning the possible influence of certain features of the objective situation. The experiment presented a condition somewhat similar to the cloud and moon illusion. The observer was seated in a dark room and was required to judge as to the relative motion of two small lights whose intensities were such that no other objects were visible. By this procedure it was hoped that the judgments might be based mainly upon certain characteristics of the two lights rather than upon any perceptible relation between them and the observer.

Two 2 c.p. electric lights were each enclosed within a

small wooden box containing a small circular diaphragm opening covered with ground glass. Each box was placed upon a horizontal double rod track. The vertical distance between the centers of the two lights was 72 mm. Between the two tracks was a piston which was attached to a metal disc, and this disc was rotated by a motor with a worm gear speed reducer. By an appropriate device either one or both of the light boxes could be easily and quickly attached to or disengaged from the moving piston without stopping the motor. The motion imparted to the lights was thus a vibratory or pendular one.

The observer was seated at a distance of 8 ft. from the lights with his line of vision at right angles to the direction of motion. A cloth curtain screened the lights from view while the apparatus was being adjusted and set in motion. The screen was then removed and the observer was requested to fixate a specified light during four complete vibrations. The lights were again covered while the report of the subject was recorded and the apparatus adjusted for the next exposure. Twenty such judgments constituted a day's test for each subject. The subjects had been informed that either one or both of the lights might move in an irregular temporal order. As a matter of fact but one light was moved at a time, and the two lights were moved an equal number of times in each day's test of 20 trials. The observer was requested to report the movements as perceived rather than to attempt to guess at the objective situation. The reports were scored as correct or illusory. The judgment was correct when the moving light was perceived in motion and the stationary light as stable. Illusory judgments were of two sorts: Both lights were perceived as moving in opposite directions. In this case the two movements might not be equal in rate or extent. In the second case the moving light was perceived as stationary and the stationary light as moving. The relative number of the two types of illusion was not a function of the variable factors studied and hence separate tabulations are unnecessary.

The five factors of the size and intensity of the lights,

their extent and rate of motion, and the direction of fixation were chosen for study. The size of the lights was controlled by iris diaphragms. Three magnitudes were arbitrarily chosen, whose diameters were 4 mm., 15 mm., and 32 mm. These magnitudes will be termed *A*, *B*, and *C* respectively. The intensity of each light was controlled by a rheostat. Three intensities were chosen and these will be referred to as 1, 2, and 3 in their order of brightness. Intensity 1 was chosen as near the limen of visibility as possible without inducing discomfort in the observer. Intensity 3 was the maximum possible without illuminating the room to the point of visibility. Intensity 2 was approximately a mean between the other two. Since the lights were fed by a storage battery giving a constant current, it was possible to reproduce these intensities approximately by calibrating the rheostats. The extents of motion chosen were $^1/_2$ inch, 1 inch, and 2 inches. The amplitude of the movement was controlled by varying the point of attachment of the piston along the radius of the rotating disc. The rate of motion was controlled by varying its amplitude and by altering the speed of the motor by a rheostat. The rates chosen for investigation were $^1/_4$ inch, $^1/_2$ inch, 1 inch and 2 inches per second. The conditions were arranged so that the moving and the stationary lights were fixated an equal number of times. The upper light was fixated during one day's test of twenty trials and the lower light was then fixated on the succeeding day. Since the upper light moved in one half of the trials, fixation was distributed equally between the stationary and the moving lights. It was thus possible to determine which direction of fixation was the more conducive to correct perception.

Some illusions were obtained for practically all experimental conditions. The efficacy of any factor must thus be determined from the relative frequency with which correct judgments were obtained as that factor was varied. The percentage frequency of correct judgments was determined for one condition and this value was compared with that obtained for a second condition. For the individual records

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we utilized Yule's formula, standard deviation $= \sqrt{pq/n}$, where n is the number of judgments and p and q represent the percentages of correct and wrong responses. Unless otherwise stated, the number of judgments for each condition was 80. In general any difference of at least 12 between two percentage frequencies for an individual is significant. The averages of the individual records for the group are also given in the tables. A difference of 10 in these values indicates a high degree of probability.

1. *Effect of Size.*—The percentage frequencies for the variations of size are given in Table I. The first vertical column specifies the magnitudes employed. In the first condition the magnitude of both lights was *A*. In the second condition the size of the lower light was *A* and that of the upper light was *B*. In the third condition the magnitude of the upper light was changed to *C*. The horizontal rows of figures are the percentage values for the individuals and the average values for the group. Below are specified the various conditions which were kept constant as the magnitudes of the lights were altered. The intensity of both lights was 1, the amplitude of movement was 1 inch, the rate of motion was $^1/_2$ inch per second, and each of the two lights was moved and was fixated the same number of times.

TABLE I.

PERCENTAGES OF CORRECT PERCEPTIONS WITH VARIATIONS OF SIZE

Sizes	J.	K.	L.	M.	S.	Ave.
1. *A–A*	47	22	49	69	34	44
2. *A–B*	54	29	75	82	32	54
3. *A–C*	50	52	66	77	46	58

Constant conditions: Intensities, 1; Amplitude, 1 in.; Rate, ½ in. per sec.; Equal number of movements and fixations.

Conditions 2 and 3, as compared with 1, are evidently conducive to perceptual accuracy. With those conditions the individual percentage values are the larger in nine of the ten comparisons, and five of these are statistically significant. The average values are also the larger, the differences in both cases being significant.

Comparing conditions 2 and 3, two of the individual records favor the third condition and both of these are significant. The average values also indicate the greater efficacy of the third condition, but the difference between them is slight. The records do not permit of any very confident statements. Either we may say that the two conditions do not differ in efficacy, or that the third condition is the more effective with certain individuals.

The comparative data are ambiguous in one respect. It is impossible to determine from this experiment whether the number of correct perceptions is a function of relative or absolute size. On the one hand it is possible to assume that the perceptual accuracy is greater when the two objects are unequal in size than when they have the same magnitude, and that the accuracy of some individuals is proportional to the degree of this inequality. On the other hand it is equally valid to conclude that perceptual accuracy varies directly with the magnitude of the combined areas of the two objects.

2. *Influence of Intensity.*—Three intensity conditions were investigated. In the first the intensity of the lower light was 1, and that of the upper was 2. In the second condition the intensity of both lights was 2, while in the third condition the intensity of the upper light was changed to 3. The percentage frequencies of correct judgments for the three conditions are given in Table II.

TABLE II

PERCENTAGES OF CORRECT JUDGMENTS WITH VARIATIONS OF INTENSITY

Intensities	B.	C.	Ha.	Jo.	P.	Ave.
I. 2–1	52	35	81	54	61	57
II. 2–2	22	19	56	27	51	35
III. 2–3	31	27	56	44	50	41

Constant conditions: Magnitudes, 2; Amplitude, 1 inch; Rate ½ inch per sec.; Both lights fixated and moved an equal number of times.

Condition I. gives the maximum of perceptual accuracy. Its values are the largest for each individual and for the group as a whole, and of these ten individual comparisons six are significant.

Condition III. is slightly more effective than II. Three individuals secured the larger values for this condition and one of these comparisons is significant. The remaining two individuals of the group gave practically identical records for the two conditions.

Perceptual accuracy is thus a function of both relative and absolute intensity. On the one hand an inequality in the intensity of the two lights gives more correct judgments than does equality. When both lights are unequal in brightness, the greater number of correct responses are secured with the lower illumination. Of the two factors, the degree of illumination is possibly the more effective one.

3. *Amplitude of Motion.*—The percentages of correct judgments with variations of the amplitude of movement are given in Table III. Our apparatus permitted but two amplitudes for each rate of motion.

TABLE III

PERCENTAGES OF CORRECT JUDGMENTS WITH VARIATIONS OF AMPLITUDE

Amplitudes	Ba.	D.	G.	H.	Mi.	Ave.
1. When rate of motion is ½ inch per sec.						
½ inch	72	47	26	20	16	36
1 inch	70	42	24	31	15	36
2. When rate of motion is 1 inch per sec.						
1 inch	79	41	27	42	26	43
2 inch	94	49	27	11	22	41

Constant conditions: Intensities, 2; Sizes, *A*; Equal distribution of movements and fixations between the two lights.

The ability to perceive correctly does not appear to depend in any pronounced manner upon the amplitude of motion. Six of the ten individual comparisons indicate the greater efficiency of the smaller extents of motion and one of these is significant; three comparisons indicate that more correct perceptions are possible with the larger movements and one of these is significant; one comparison favors neither assumption. The results of but one of the five individuals (Mi.) consistently favor either assumption; both comparative values

of this subject indicate the greater efficacy of the lesser amplitudes, but the differences in both comparisons are quite small. From these data one is not justified in asserting that perceptual accuracy is dependent upon the amplitude of motion so far as this factor was varied.

4. *Influence of Rate of Motion.*—Table IV. gives the percentages of correct judgments for variations of rate of motion. Our apparatus permitted of but two variations of speed for each amplitude of movement.

TABLE IV

PERCENTAGES OF CORRECT JUDGMENTS WITH VARIATIONS OF RATE OF MOTION

Rates of Motion	Ba.	D.	G.	H.	Mi.	Ave.
1. With amplitude of ½ inch						
¼ inch per sec.	57	45	2	15	20	27
½ inch per sec.	72	47	26	20	16	36
2. With amplitude of 1 inch						
½ inch per sec.	70	42	24	31	14	36
1 inch per sec.	79	41	27	42	26	43
3. With amplitude of 2 inches						
1 inch per sec.	94	49	27	11	22	41
2 inch per sec.	51	66	62	16	17	40

Constant conditions: Sizes, *A*; Intensities, 2; Equal distribution of movements and fixations between the two lights.

In each of the first two series the faster rate gives the greater number of correct judgments in four of the five individual comparisons; of the eight favorable comparisons four are significant. In the third series three of the individual comparisons favor the faster rate. Two individuals, G. and H., were invariably more accurate with the faster rates. Individuals Ba. and D. were more accurate with the faster rate in two of the three series. Mi. was more accurate with the faster rate in but one of the series.

The facts indicate that the rate of motion is effective at least with some individuals, and that in the majority of cases perceptual accuracy is greater for the faster rates of motion.

5. *Individual Differences in Perceptive Ability.*—In Table V. the individuals of each group are ranked according to their ability to perceive the objective situation correctly. Group 1 was composed of five subjects. These individuals were tested for three series in which the size of the lights was varied (See Table I.). These individuals were ranked ac-

TABLE V

RANKS OF INDIVIDUALS IN RESPECT TO NUMBER OF CORRECT JUDGMENTS

Group 1

	M.	L.	J.	S.	K.
	1	2	3	4	5
	1	2	3	4	5
	1	2	4	5	3
Total.....	3	6	10	13	13

Group 2

	Ha.	P.	Jo.	B.	C.
	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5
Total.....	3	6	9	12	15

Group 3

	Ba.	D.	G.	H.	Mi.
	1	2	5	4	3
	1	2	3	4	5
	1	2	4	3	5
	1	3	4	2	5
	1	2	3	5	4
	3	1	2	5	4
Total.....	8	12	21	23	26

cording to the number of correct judgments. Subject M. secured the highest percentage in all three tests and is ranked first three times with a total score of 3. Subject L. stood second in every case with a total score of 6. From these data it is obvious that individuals differ in their ability to perceive the situation correctly. In group 2 the five subjects maintained the same relative ranking in all three tests. Some individuals are able to perceive a relative movement situation with a high degree of accuracy while other indivi-

duals are more prone to perceptual illusions. It is possible that this experiment might constitute a good test for determining the relative suggestibility of different individuals.

6. *Influence of Direction of Fixation.*—In any series of 80 judgments, the moving light was fixated 40 times and the stationary light was fixated an equal number of times. The percentages of correct judgments for each kind of fixation were computed for each individual for all experimental conditions. These percentage values are given in Table VI.

TABLE VI

PERCENTAGES OF CORRECT JUDGMENTS WITH VARIATION OF FIXATION

Fixation	L.	M.	G.
Moving	50 70 60	65 90 72	25 27 27 27 2 45
Stationary	48 80 72	72 75 82	22 25 27 27 2 57
	Ha.	Jo.	Ba.
Moving	65 57 75	5 47 42	55 50 75 87 67 2
Stationary	47 56 87	50 40 65	85 95 82 100 47 100
	S.	B.	H.
Moving	5 15 40	7 12 35	20 5 12 5 5 5
Stationary	62 50 47	37 50 70	42 35 72 17 25 27
	J.	C.	Mi.
Moving	57 77 72	30 52 62	5 2 0 0 30 0
Stationary	38 30 27	7 2 7	22 30 52 45 10 35
	P.	K.	D.
Moving	42 45 35	15 27 42	32 45 17 30 30 35
Stationary	60 55 87	30 30 62	52 50 65 67 60 97

Subject L was tested for three experimental conditions. His percentages of correct perceptions when the moving light was fixated were 50, 70 and 60. These values are to be compared with the percentages of 48, 80 and 72 secured when the stationary light was observed. Each percentage value of the table is based upon 40 judgments. With this number of cases a probability that direction of fixation is an effective factor in the perception of relative motion will be indicated by any difference of 20 or more.

With four subjects, L., M., G., and Ha., the direction of fixation did not appreciably influence the number of correct

perceptions. The comparative values do not consistently favor either mode of fixation, and none of the differences are large enough to be significant.

With two subjects, J. and C., fixation of the moving object is the more conducive to perceptual accuracy. This mode of fixation is favored in all comparisons and all of the differences are significant.

With the remaining nine individuals, the greater perceptual efficiency was attained by observing the stationary object. For these subjects 36 of the 39 comparisons favor this mode of fixation, and of these 36 comparative values 27 are significant.

TABLE VII

PERCENTAGES OF CORRECT JUDGMENTS WHEN EACH LIGHT WAS STATIONARY

Subject	Stable Light	Experimental Condition						
		1	2	3	4	5	6	Ave.
Ba.	Upper	60	72	62	80	95	52	70
	Lower	80	85	82	35	92	50	71
D.	Upper	30	27	42	30	27	57	35
	Lower	55	55	52	60	70	75	61
G.	Upper	45	42	42	2	40	60	38
	Lower	2	12	10	2	15	42	14
H.	Upper	30	42	15	15	12	12	21
	Lower	32	42	25	15	10	20	24
Mi.	Upper	22	30	25	40	25	17	26
	Lower	5	22	7	0	20	17	12

Constant conditions: Lights equal in size and intensity; Equal number of fixations and movements.

7. *The Influence of Position.*—In Table VII. are listed the percentages of correct judgments when the upper light was stationary as compared with the percentages when the lower light was immobile. The upper and lower lights were equal in size and intensity for all six experimental conditions. The two lights were fixated an equal number of times. The data are given only for the third group of subjects, since the two objects were not always equal in size or intensity for groups 1 and 2. In the first experimental condition, Ba. correctly perceived 60 per cent. of the 40 cases in which the upper light was stationary and the lower moving. He perceived correctly 80 per cent. of the 40 cases in which the

lower light was stable and the upper one was moving. This comparison was instituted to determine whether either position tends to be associated with stability. A difference of 20 in the individual values and of 11 in the average values indicates a probability of the efficacy of the position factor.

Position did not exert any appreciably consistent effect with subjects Ba. and H.

Subject D. consistently perceived the situation more correctly when the lower light was stable and the upper in motion than in the reverse case. Five of the seven comparisons are statistically significant. With this individual the lower position is associated with immobility and the upper one with motility.

Subjects G. and Mi. exhibited more correct perceptions when the stationary light occupied the upper position. Both subjects were consistent in this preference with one exception in which the two percentage values were equal. These individuals tend to associate stability with the upper position.

8. *Summary.*—The subjects were required to judge concerning the relative motion of two lights, one of which was always stationary.

Perceptual accuracy was promoted either by a difference in size of the two lights or by an increase in their combined area. Possibly both conditions may have been operative.

Perceptual accuracy was favored by an inequality of brightness of the two lights and by a decrease of their combined illumination.

The amplitude or extent of motion so far as this factor was varied did not exert any effect upon perceptual ability.

Perception was generally more accurate with the faster rates of motion.

The individuals exhibited consistent differences in their ability to perceive the situation correctly.

The majority of the subjects were able to perceive the situation more correctly with stationary eyes, *i.e.*, when the stationary light was fixated and the moving light was perceived with indirect vision. Some individuals gave the better records when the moving light was fixated. Other

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individuals were able to judge equally well for both conditions of fixation.

Some individuals were able to perceive more correctly when the stationary light occupied the upper position, while the opposite condition obtained for other subjects. The position of the stationary light was not effective for other observers.

The influence of such factors as the degree of illumination and the rate of motion upon perceptual ability is obvious.

The influence of fixation indicates that certain individuals solved the problem in part by an indirect reference of one of the objects to the organism. It is practically impossible to exclude all spatial reference of the objects to the observer. Some subjects were apparently able to detect the moving object by means of the eye sensitivity involved in following it. Others were able to identify the stationary object by the absence of eye movement while fixating it. Individual differences in this respect do not admit of a ready explanation.

We have no explanatory suggestions to offer for the influence of inequalities of size and brightness.

The influence of the position of the stationary light may be explained by the supposition that the subjects apprehended the perceptual situation much as though the two lights constituted the ends of a swinging pendulum. Individuals who exhibited any tendency to conceive the situation as similar to a simple suspended pendulum will obviously associate the upper position with stability and hence will make a greater number of correct judgments when the stationary light occupies this position. On the contrary those who preferred to regard the situation as analogous to a metronome will associate the lower position with immobility and give the better records when the lower light is stationary. Certain subjects were not influenced by the position of the stationary light. This fact may be explained by supposing that these subjects conceived the situation as a compound pendulum with the center of rotation located between the two lights, that they were able to assume equally well either of the first two attitudes, or that they failed to adopt any pendular attitude.

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Individual differences in perceptive ability may likewise be explained in part by differences in apperceptive attitude. Individuals who are able to adapt the first two attitudes to the objective sequence will naturally make unusually high scores. Subjects inclined to regard the movements as similar to a compound pendulum will obviously make poor records. No introspective records were taken in regard to these apperceptive attitudes during the experimentation. The hypothesis is suggested on the basis of its a priori plausibility.

The possibility that the subjects may adopt some pendular attitude toward the situation suggests that it is advisable in future experiments to eliminate this complicating condition by locating the two lights in a horizontal plane.

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A NEW OBJECTIVE TEST FOR VERBAL IMAGERY TYPES

BY SAMUEL D. ROBBINS

From the Psychological Laboratory, Harvard University

The purpose of this experiment was to devise an objective test by means of which the vividness of auditory, visual, and kinæsthetic verbal imagery of persons who cannot be depended upon for intelligent introspection may be quickly and accurately determined.

I had for subjects six students who were studying psychology. Four of these subjects were men, two were women. Two other women were subjects only in the first test described. No subject was under twenty years of age or over thirty. All of the women were born and educated in this country and had all their lives spoken English fluently. All the men, on the other hand, were born and educated in foreign lands, had spoken English but a few years, had a distinctly foreign accent, and had limited vocabularies of English words differing much from each other.

A number of series of card pairs containing a single column of five monosyllabic nonsense words of three or four letters were very carefully typewritten (double spaced) so as to look exactly alike except for one word which differed from the corresponding word on the other card in a single letter. The following types of nonsense groups were tabulated separately, the card pairs being shuffled so that the subject could not predict the nature of the next change: (1) the spelling was changed without altering the pronunciation, as veek-veak; (2) two long vowels were exchanged, as zoke-zake; (3) a short vowel was exchanged for the same long vowel, as koss-kose, there being another change, a visual one, in most cases; (4) two short vowels were exchanged, as meb-mib; (5) two consonants were exchanged which gave quite different auditory and kinæsthetic impressions, as aze-ane;

(6) two consonants were exchanged which sounded much alike but gave quite a different kinæsthetic impression in a trial series, as miz-niz; (7) two consonants were exchanged which gave about the same auditory and kinæsthetic impression in a trial series, as bim-pim. As some changes necessitated four-letter words, at least one four-letter word appeared on each pair of cards. There was an equal number of changes at the beginning, middle, and end of the word and for each of the five positions of the word in the column; hence the position of the change could not be predicted.

The nonsense words were given to the subjects in three ways: (1) They were read loud by the experimenter, the subject being careful not to repeat, spell, or visualize the word; (2) the subject repeated each word as it was read to him before the next word was read, being careful not to spell or visualize it; and (3) the cards were exposed in a tachistoscope and the subject was asked to whisper each word. (Subjects were asked to whisper rather than to read aloud because most stammerers can whisper without stammering, and these results are later to be compared with those obtained from stammerers.) The first method permitted the subject to employ auditory imagery alone, the second permitted both auditory and kinæsthetic imagery, and the third auditory, kinæsthetic, and visual imagery. There was an interval of five seconds between the reading of the first card of a pair and the first word of the second card, during which the subject was requested not to think of any of the words on the first card.

The subjects followed this direction remarkably well, and formed surprisingly few associations with these nonsense words. They forgot the nonsense words on the earlier cards before the later cards were read, hence memory of words on the first test played little if any part in the recognition of changes by the second and third methods; changes which were detected when the cards were read by the first method were frequently not detected when the same cards were subsequently read by the same subject by a different method. In the few cases where a change was remembered

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from a previous test, the letter 'A' was written on the record so that this change could be omitted in compiling the results if enough associations were formed to alter the averages materially. Each series was read at the speed which each subject found most satisfactory on a trial series.

The subjects were asked to report on a scale of 0 to 3 whether there was a change. 0 indicated that there was no change or that the subject did not know whether there was a change. 1 meant there might have been a change of which the subject was not at all sure. 2 denoted that the subject was pretty sure there was a change. 3 showed that the subject was positive there was a change. If a subject reported the right position of the change, he was credited the score he reported even if he gave the wrong word or could not remember the word. If he reported there was no change when there was a change, his score for the change was 0. As a matter of fact, every card was changed, except when a subject reported so many changes in succession that I feared he would mistrust my instructions that some pairs of cards had one change and others had no change.

The subject was also required to report what the changed word was on both cards, stating how sure he was of the word he reported on the same scale of 0 to 3. For his word score, he was given the score of the word of which he was less sure. If he forgot one of the words or reported one or both words incorrectly his word score was 0. If, on the other hand, he detected the main change correctly but made the same mistake in some minor letter of both words, he was given full credit.

Each subject was given a long trial series[1] by each method before the cards representing the scores compiled in table 1 were used. Subjects were therefore familiar with the experiment before the series reported was used.

Table I. shows the average score each subject obtained in each of the seven groups of changes by each of the three methods of presentation. The four columns in division 6

[1] One trial series consisted of sense words. This series was discarded because the words proved unequally familiar to the men of foreign birth.

TABLE I

TABLE I

AVERAGE SCORE FOR DETECTING EACH TYPE OF CHANGE

Subject	1	2				3				4				5			
	Change Only in Spelling	Long Vowel				Short Vowel for Same Long One				Short Vowel				Consonants Having Different Auditory and Kinæsthetic Impressions			
	W.	L.	R.	W.	Av.	L.	R.	W.	Av.	L.	R.	W.	Av.	L.	R.	W.	Av.
W	1.50	2.70	2.35	2.95	2.67	3.00	3.00	3.00	3.00	1.75	2.00	2.40	2.05	1.50	2.40	2.40	2.10
E	1.50	2.70	2.70	3.00	2.80	3.00	2.40	3.00	2.80	1.75	2.10	2.55	2.13	1.40	1.20	1.80	1.47
R	1.90	3.00	2.95	2.85	2.93	3.00	3.00	3.00	3.00	2.40	1.20	2.95	2.18	3.00	2.20	2.10	2.43
M	1.70	3.00	2.85	3.00	2.95	3.00	3.00	3.00	3.00	2.30	1.65	1.80	1.92	2.40	1.80	2.50	2.23
D	1.70	3.00	2.55	3.00	2.85	2.40	3.00	3.00	2.80	1.50	1.50	2.20	1.73	1.00	1.40	2.40	1.60
T	2.40	2.70	2.70	3.00	2.80	2.00	1.20	2.80	2.00	1.10	1.05	2.75	1.63	1.20	1.50	2.00	1.57
A	0.60	2.55	1.95	2.40	2.30	2.40	2.40	1.40	2.07	0.80	0.95	0.95	0.90	0.50	0.30	0.90	0.57
S	1.30	2.15	2.25	1.85	2.08	2.80	2.40	1.80	2.33	1.20	0.80	1.05	1.02	0.20	0.40	1.10	0.57
Av. for men	1.55	2.60	2.46	2.52	2.53	2.55	2.25	2.25	2.35	1.38	1.00	1.92	1.43	1.22	1.11	1.52	1.28
Av. for women	1.60	2.85	2.61	2.99	2.82	2.85	2.85	3.00	2.90	1.82	1.81	2.24	1.96	1.57	1.70	2.27	1.85
Av for all O's.	1.58	2.72	2.54	2.76	2.67	2.70	2.55	2.62	2.63	1.60	1.41	2.08	1.69	1.40	1.40	1.90	1.57

Subject	6				7				8				9			
	Consonants Having Different Kinæsthetic Impressions				Consonants Having Similar Auditory and Kinæsthetic Impressions				Average Change Score for all Types.				Average Word Score for all Types			
	L.	R.	W.	Av.	L.	R.	W.	Av.	L.	R.	W.	Av.	L.	R.	W.	Av.
W	2.13	2.13	2.40	2.22	1.13	1.60	2.40	1.71	1.98	2.14	2.45	2.20	1.39	1.55	2.22	1.74
E	1.00	1.73	2.20	1.64	1.40	1.80	1.60	1.60	1.81	2.04	2.27	2.05	1.21	1.88	1.93	1.68
R	1.07	0.47	2.20	1.24	0.27	0.00	1.20	0.49	2.04	1.49	2.34	1.97	1.76	1.25	2.06	1.71
M	0.60	1.27	1.53	1.13	1.20	0.53	1.47	1.07	2.02	1.76	2.08	1.96	0.79	0.93	1.47	1.08
D	0.80	0.80	1.80	1.24	0.67	0.67	1.87	1.07	1.58	1.55	2.26	1.82	0.94	0.85	2.02	1.30
T	0.60	0.73	2.13	1.16	0.60	0.33	2.20	1.04	1.36	1.32	2.50	1.76	0.58	0.76	2.00	1.15
A	0.20	0.07	0.80	0.36	0.20	0.60	0.40	0.40	1.06	0.98	1.12	1.06	0.79	0.42	0.73	0.65
S	0.13	0.07	0.60	0.22	0.13	0.07	0.33	0.18	1.02	0.93	1.10	1.02	0.68	0.68	0.85	0.74
Av. for men	0.50	0.33	1.43	0.86	0.30	0.25	1.03	0.53	1.37	1.18	1.77	1.45	0.95	0.77	1.41	1.04
Av. for women	1.13	1.48	1.98	1.53	1.10	1.15	1.83	1.36	1.85	1.88	2.27	2.01	1.08	1.30	1.91	1.43
Av. for all O's	0.82	0.91	1.71	1.14	0.70	0.70	1.43	0.94	1.61	1.53	2.02	1.73	1.02	1.04	1.66	1.24

give the average word scores for all of the groups taken as a whole; the other columns give the average change scores. In this table there are four columns each in divisions 2, 3, 4, 5, 6, 7, 8 and 9. Of these four columns the one headed L contains each subject's average score in the first test where he *listened* to the words as they were read to him; that marked R contains those in the second test where the subject *repeated* each word after the experimenter; that marked W contains those in the third test where the subject *whispered* the words exposed in the tachistoscope; and that marked Av. contains the *average* of the other three columns. Division 1 is not divided into four columns because the subject only whispered those sets in which the changed word was spelled differently yet pronounced exactly like the first word exposed in the tachistoscope. At the bottom of this table are given the average scores in each test for the men, for the women, and for all eight subjects. Subjects D, E, M and W are women, and subjects A, R, S and T are men.

This table shows that the women as a class did much better in every test than the men and that subjects who did especially well in detecting some change also did especially well in remembering exactly what word appeared on each card, the correlation[1] being + 0.929.

This table shows also that long vowel changes are much more readily detected than short vowel changes; it makes little if any difference whether a long vowel is changed to the same short vowel or to a different long vowel. Conspicuous consonant changes are noted almost as readily as short vowel changes, inconspicuous ones far less frequently. The whispering test gave the highest and the most uniform scores for all subjects. The subject of vowel versus consonant changes will be more thoroughly discussed in a later paper comparing the verbal imagery of normal speakers with that of stammerers.

Columns 1, 2, 3 and 4 of Table II. give the vividness of each subject's verbal imagery on a scale of 0 to 3 as

[1] All correlations were derived from the formula, $r = \frac{\Sigma(xy)}{\sqrt{(\Sigma x^2)(\Sigma y^2)}}$, where x and y are the deviations of the two traits from their mean in any single individual

determined from his ability to detect changes by auditory imagery, kinæsthetic imagery, and visual imagery. These ranks are determined as follows: The visual rank is the average score of the subject in detecting by whispering changes

TABLE II

COMPARATIVE EFFICIENCY OF DIFFERENT TYPES OF VERBAL IMAGERY

Subject	1 Auditory	2 Visual	3 Kinæsthetic	4 Total	5 Spelling Backward	6 Copying Long Nonsense Words	7 Copying Perverted and Inverted Print	8 Writing Perverted and Inverted	9 Column 8 of Table 1
W	2.5	1.5	1.7	5.7	0.82	5	7	49	2.20
R	2.8	2.0	0.4	5.2	10.12	49	28	3	1.97
T	1.9	2.4	0.9	5.2	1.33	13	77	7	1.76
D	2.3	1.7	1.1	5.1	6.03	1	34	201	1.82
S	2.1	1.3	0.1	3.5	7.25	25	80	20	1.02
A	1.9	0.6	0.1	2.6	22.05	43	157	171	1.06
Av. for women	2.5	1.6	1.5	5.6	3.43	3	21	125	2.01
Av. for men	2.2	1.6	0.4	4.1	10.19	32	106	50	1.45
Av. for all O's	2.3	1.6	0.9	4.9	7.93	23	64	75	1.64
Correlation with col. 4					+0.90 without R	+0.94 without R	+0.90	+0.83 for men	+0.95

in words that are pronounced alike but spelled differently, such as zeat-zeet. The auditory rank is the average score obtained by the subject in detecting vowel changes in all three vowel groups when these are read aloud to him. Trial experiments showed that kinæsthetic imagery played little if any part in these groups and that it actually reduced the score in many cases. The kinæsthetic rank is the average score the subject obtained when he repeated after the experimenter those cards in which changes had been made in words which sound much alike but give quite a different kinæsthetic impression (such as vad-vab), and in which he failed to detect changes when they were read aloud to him. The kinæsthetic and auditory imagery are so closely connected that I could find no better way to separate them. Trial series showed that there is little likelihood the subject will be able to detect a second time a slight auditory change which he does not detect the first time by the same method. The

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changes in this group were so chosen from the introspections on a trial series as to reduce to a minimum the auditory element, and to make the kinæsthetic element as prominent as possible. There is a close correlation, + 0.950, between the average ranks of subjects for the entire series as recorded in the average column in division 8 in Table I. and the total ranks obtained by adding together their three ranks in columns 1, 2, and 3 of Table II. as recorded in column 4. It seems to make little difference, therefore, what type of imagery is employed for the test as a whole; the subject possessing the greater sum total of verbal imagery attains the higher rank in this experiment.

Before beginning any tests, each subject was asked to answer the questionnaire given on pages 195–200 of E. B. Titchener's 'Experimental Psychology, Student's Manual, Qualitative.' A careful examination of the question blanks showed there was no correlation between verbal and non-verbal imagery. It is incorrect to assume, therefore, that because one has very vivid non-verbal imagery of a given type he must also have very vivid verbal imagery of the same type.

The four experiments which follow were performed to confirm the reliability of the preceding test.

After the test with nonsense words had been completed, each subject was asked to spell backward twenty words of increasing length, beginning with two letters and ending with twenty-two, and to report the method he employed for both the short and the long words. The experimenter kept a record of the time spent in spelling each word and of the number of errors. It is obvious that the efficiency of a subject in performing such a task depends upon both the speed and the accuracy with which it is accomplished; the greater the speed and the fewer the mistakes, the higher the efficiency. If this efficiency is represented by the product of the time in which a unit of the task is performed by the number of errors made, the lower product will denote the greater efficiency. These products for the six subjects who performed this test will be found in column 5 of Table II.

It will be seen that, with the exception of R, the lower product corresponds in every case with the higher sum total of verbal imagery recorded in column 4, the correlation without R being + 0.90. This shows that efficiency in this test is proportional to the total amount possessed by the subject of verbal imagery of types useful in performing the task. R reported that he employed visual imagery alone for this test because he believed it would increase his speed. As he possessed the strongest auditory imagery of the six subjects and as the trial series showed him to have about the weakest visual imagery, he should have employed auditory imagery or a combination of both, rather than visual imagery.

After spelling backward, each subject was asked to copy fifteen long nonsense words of from twelve to twenty-eight letters, to make a dash every time he looked at the copy, and to report how he copied these words. The experimenter kept a record of the time spent in copying each word and of the number of errors. Column 6 of Table II. gives the relative efficiency of the subjects in this test, this being the product of the average time in seconds it took the subject to copy each word by the average number of mistakes per word; and, as in the spelling backward test, the lower the product, the greater the efficiency. With the exception of R, the lower product corresponds closely with the higher sum total of verbal imagery, the correlation being + 0.94 without R. R employed auditory imagery alone, looking at the first twelve words but once and spelling them as he pronounced them. As long groups of consonants made it impossible to pronounce these words, he naturally made many mistakes.

After copying these long words, each subject was asked to copy two or three lines of each of six type-written selections, arranged in the following ways: perverted, backward perverted, inverted, backward inverted, perverted and inverted, and backward perverted and inverted. By backward I mean spelled from right to left instead of from left to right. By perverted I mean written so as to be read in a mirror. By inverted I mean written so as to be read by one facing the writer. The subjects introspected as in the previous

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tests, and the experimenter kept a record of the time it took to copy each line and of the number of mistakes. Column 7 of Table II. gives the relative efficiency of subjects in this test. This efficiency is denoted by the product of the average time per line in minutes by the total number of mistakes; and here again the less the product, the greater the efficiency. With the exception of T, the lower product corresponds in every case with the higher sum total of verbal imagery, the correlation being + 0.90 even with T included. T used an unfortunate method on the first line which caused him to make nearly as many mistakes as he made on the other twelve lines combined; when this one line is discarded, his score becomes practically equal to D's.

After copying these unusual kinds of printing, the subject was asked to write 'United States of America' so that it would be read normally by a person facing him; 'Harvard University' so that it would be read normally *through* the paper without inverting it; 'Cambridge, Massachusetts' so that it would be read normally through the paper *inverted;* and 'European War' so that it would be read forward *through* the paper without inverting it but with each letter perverted. The subject introspected as before and the experimenter kept a record of the time required to write each phrase and of the number of errors. Column 8 of Table II. gives the relative efficiency of the subjects in this test. Here the product of the average time per letter in seconds by the total number of mistakes gives the efficiency; so, as usual, the smaller product denotes the greater efficiency. With the exception of the women, who found this test far more difficult than did the men, there is a fairly good correlation, + 0.83, between the efficiency of each subject in this test and his total verbal imagery score.

As all of the spelling, copying, and writing tests just described require the coöperation of auditory, kinæsthetic, and visual verbal imagery, the high correlation between the efficiency of a subject in these tests and his total verbal imagery score (which is the sum of the scores of the separate types of verbal imagery used by a majority of the subjects in

performing each of these tasks), shows that the efficiency of subjects in performing a given task is proportional, approximately, to the sum of the scores of the separate types of verbal imagery commonly employed in performing that task.

Any one wishing to use a similar but shorter test can score auditory imagery by reading aloud to his subjects thirty cards such as I used containing the following vowel changes: koss-kose, nume-nurm, dack-dake, girn-gine, neff-neaf, afe-ofe, eag-oag, ane-une, ipe-epe, fese-fose, bose-buse, nafe-nufe, vife-vefe, obe-ube, zoke-zake; ank-enk, ald-uld, nef-naf, ilt-ult, nop-nep, baf-bof, eft-uft, ilm-ulm, zep-zop, alk-olk, maz-muz, oln-uln, mev-muv, tig-teg, zab-zib. These cards should be well shuffled with one another and with a second group containing at least twenty consonant changes which give a distinctly different kinæsthetic impression such as the following: ubs-uds, vab-vad, nis-niz, gem-gen, bis-tis, vot-vob, sef-zef, tov-pov, ips-ids, zup-zut, pax-dax, mub-nub, abf-atf, ost-ozt, emk-enk. These groups should then be repeated after the experimenter, and in the case of the kinæsthetic score the record should be kept only of those consonant changes detected that were not noticed when the experimenter first read the second group. The third group, used for scoring visual imagery, should contain at least ten nonsense words which are spelled differently yet pronounced alike such as mije-mige, bick-bik, fis-fiss, gax-gaks, veet-veat, doxe-doax, klab-clab, zoll-zol, boze-bose, sibe-cibe. After the subject has thus repeated the first and second groups after the experimenter, the third group should be shuffled with ten pairs from other groups and exposed in a tachistoscope long enough for the subject to read each card aloud. The experiment should be conducted and the results scored as outlined at the beginning of this report.

Summary

1. Women possess more vivid verbal imagery than men.

2. Long vowels receive more attention than any other letters.

3. Short vowels receive much less attention than do long vowels.

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4. Consonants receive less attention than vowels.

5. A change of one letter in a pair of nonsense words can be detected most readily if the subject reads the words aloud from copy.

6. Those persons will perform a given mental task most efficiently who possess the most vivid types of verbal imagery commonly employed to accomplish that task.

NOTE ON THE VERBAL IMAGERY OF STAMMERERS AND NORMAL SPEAKERS.[1]

I stated that the subject of vowel versus consonant changes would be discussed in a later paper comparing the verbal imagery of normal speakers with that of stammerers. As my experiment shows that the average verbal imagery for twelve normal speakers and twelve stammerers is practically identical, a brief note will suffice to summarize my results.

The same objective test described in the above named article was given to four additional speakers, two of them men, and two women, and to twelve stammerers, six of them men, and six women; and the average score for the twelve normal subjects and the twelve stammering subjects was compiled as in my earlier article.

The average change score showed that the stammerers detected changes a very little better than the normal speakers when the card pairs were read to them, 1.7 compared with 1.6, and that the normal speakers detected changes a little more readily when they looked at the card pairs and whispered them, 2.0 compared with 1.8. They averaged the same, 1.5, when they repeated the card pairs after the experimenter, and averaged the same, 1.7, when all three methods of presentation were averaged together.

The vividness of each subject's visual, kinaesthetic, and auditory verbal imagery was determined as in the earlier paper and the stammerers and normal speakers were found to have the same average auditory imagery, 2.2, and the same average kinaesthetic imagery, 0.8. The visual verbal imagery of the

[1] Prepared after the article was in type.

stammerers was but 75 per cent. of that of the normal speakers, however, 1.2 compared with 1.6. As few persons employ visual verbal imagery to any extent in speech, there is obviously nothing in verbal imagery of any kind to account for stammering. There is a suggestion, however, that certain letters may attract the stammerer's attention unduly; this problem I am now investigating. The following facts came out in this investigation.

The stammerers did not detect the long vowel changes so readily as the normal speakers, 2.4 compared with 2.7 in the listening test and 2.2 compared with 2.6 in the repeating test; yet they detected the short vowel changes more readily, 1.9 compared with 1.6 in the listening test and 1.7 compared with 1.4 in the repeating test.

Averaging the three series composed of the three types of vowel changes I found that the stammerers and normal speakers scored alike, 2.2, on the listening tests, and that the stammerers did not do quite so well as the normal speakers on the repeating tests, 1.9 compared with 2.1, or on the whispering tests, 2.4 compared with 2.5.

Averaging the three series composed of the three types of consonant changes I found that the stammerers excelled in the listening tests, 1.15 compared with 0.95, and on the repeating tests, 1.05 compared with 0.95, but scored only 1.44 compared with the normal speakers' score of 1.68 on the whispering tests, the difference being due, no doubt, to the better visual imagery of the normal speakers. The average for the three methods of presentation was the same for normal speakers and stammerers, 1.19. The maximum and the minimum scores averaged the same for stammerers and normal speakers in the vowel changes and the maximums averaged the same in the consonant changes, but the normal speakers' minimums averaged twice as low as the stammerers in the consonant changes. It would seem, therefore, that stammerers pay more attention to consonants than do normal speakers; this is confirmed by the work I have done in connection with the correction of stammering.

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A FUNCTIONAL INTERPRETATION OF HUMAN INSTINCTS

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Recent developments in the study of human behavior make it possible to begin a reinterpretation of instincts and related phenomena which today admittedly constitute the darkest chapter in psychology. In this paper the writer attempts to suggest a functional interpretation of human instincts and their integration into instinctive conduct. The functional psychologist aims to start from an unbiased naturalistic standpoint and therefore hopes to achieve some progress in the understanding of some of the adaptational equipment of human beings. At the very inception of such a study we observe the imperative necessity for a scrupulous discrimination between the acts which are properly called instincts, and the more complex reactions developed from them which we will call instinctive conduct or behavior.

I

The Nature of an Instinct.—An instinct is a comparatively simple and direct response to a specific stimulating object or condition. It is in fact the functioning of a connate potential reaction system[1] which is organized from simple psychophysiological dispositions or tendencies to respond to stimuli. That instincts are so highly spontaneous may be accounted for by the fact that the specific way in which the reaction system functions, depends upon the stimulating conditions. It is this moulding of the response by the surrounding con-

[1] A reaction system is a complex function involving cognitive, conative, affective, muscular, glandular and neural factors. *Cf.* Kantor, 'Conscious Behavior and the Abnormal,' *J. of Abnorm. Psychol.*, Aug., 1918. An example of a reaction system is the response, 'August, 1914' (with all its accompanying organic resonances) to the stimulation, 'when did the hostilities of the great European War begin?' This response is potential in all those who have acquired the informational reaction.

ditions which is the source of the many marvellous tales of intelligence among the lower animals.

An instinct being a primary act and therefore entirely "undebauched by learning," must be looked upon as one of the primary functional elements in the embryological development of the human organism. For the instinctive reaction patterns are functions of animal adaptation developed from the simple functions of organized matter.[1] Owing to this development instincts may be classified as (1) food-getting, and waste eliminating responses, (2) sexual reactions, (3) expressive acts, and (4) protective responses. These classes represent specific adaptations to particular adjustment-situations, that is to say concrete actions, and with the random movements and reflexes form the matrix of the entire series of human behavior.

The function of human instincts is to adapt the person to the various surroundings in which he is found, pending the development of the intelligent responses usually required for such adaptations. These modes of instinctive response develop in the species of organism during its interaction with its environment; consequently there is an entirely natural genesis of the instincts paralleling the growth of the human being in the evolutionary course of the animal species to which he belongs. Every organism possesses a series of these reaction systems which in the presence of adequate stimuli become responses. The response and the stimulus together constitute an act, that is to say, a specific adaptation. From a definitively psychological standpoint the individual at any particular moment is this series of reaction systems.

If we have correctly described the origin and development of instincts, we have sufficiently indicated that the instincts of the human organism are very different from those of the lower animals. The reaction systems, as the units of the organism on the action side, must naturally be just as diverse in dissimilar organisms as are the structural parts. Thus we find differences of a wider or narrower sort in both the mental and physiological factors of the specific functions.

[1] These are usually described by the zoölogist as irritability, metabolism, reproduction, motility, etc.

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Obviously, the most striking variation between human and animal instincts is the extreme modifiability of the former. In fact, human instincts are so distinctly transitory in character that they disappear very early from the reaction equipment of the human organism, and in the adult individual are completely absent. These human instincts become integrated into more complex types of responses, while the animal instincts remain as permanent acquisitions of the organism, and change only by becoming more adaptable through practice to the situations in which they frequently function.

The Nature of Instinctive Behavior.—In contrast to the instincts, instinctive conduct comprises adjustments which are essentially acquired tendencies of response, and in most cases constitute intelligent behavior. It must be noted, however, that the reaction systems of instinctive conduct, which, by the way, include the greatest portion of our actual responses, are developed as elaborations of a prominent core of organized innate reaction patterns. In all cases of instinctive conduct we have integrations of concrete human acts; so that if, for example, we start with the walking act of a child, the exigencies of the surrounding conditions may condition that initial act to become a locomotor response to the call of the parents, or to any other stimulating circumstance acting upon our illustrative child. The results of observations of human behavior demonstrate that the rapidity and complexity of the integrations are owing to the responsiveness of surrounding objects; that is to say, a responsive object forces the individual to apprehend the possibility and necessity of varying his response, and therefore to learn to react with a meaningful behavior to the stimulating response of the other object. This sort of interaction with the environment constitutes the basis for social phenomena of various types and is excellently illustrated by the constant interstimulation between two boys during the preliminaries of a fistic combat. In this situation each individual is intently posed in an anticipatory attitude, requiring only the slightest sign of change in position on the part of the opponent as an effective stimulus to bring about a telling response. When

we recall that a single individual can serve both as stimulating and responding object we can appreciate the importance of this self-stimulation as a factor in the rapid integration of the simpler forms of behavior.

Since the natural environment of the human organism consists primarily of responsive objects we see why the human adult has no instincts, that is, performs no acts which are actualizations of exclusively innate dispositions, but always responds with a partially acquired reaction pattern. The view that man has more instincts than the lower animals, for which James[1] is in part responsible, could only obtain credence so long as the precise nature of a conscious act remained unanalyzed. That James did not entirely ignore the facts concerning instinctive conduct is manifested by his observation that human instincts do not remain blind.[2] The physiological viewpoint, which always influenced James, prevented him from fully appreciating the psychological changes which transform instincts into more complex actions. To think of the non-rational activities of the human organism in terms of reflexes which are somehow coupled with impulses, means the capricious disavowal of the variety and richness of the instinctive forms of behavior.

The contrast between instincts and instinctive behavior is made clearer by dispelling somewhat the confusion existing in the conception of the differences between the instincts and the more simple reflexes which differ widely from the former in organization and function. The reflex action involves the functioning of a more definite and fixed reaction system than does the instinct, and the result of the stimulation is a genetically simpler form of behavior. The relative rigidity of the reflex response allows comparatively little room for adjustment between the organism and the stimulating conditions while the action system is functioning.

Further, it has been frequently observed that instincts involve a much larger conscious function than is the case with reflexes,[3] since the latter are on the whole much simpler,

[1] *Cf.* 'Principles,' pp. 393, 441.

[2] *Ibid.*, 390.

[3] Stout, 'Manual of Psychology,' 1915, p. 343.

but we must guard against the idea that reflexes are merely neuro-muscular actions.[1] While Stout is entirely correct in his assertion that 'instinctive conduct does, and reflex action does not presuppose the coöperation of intelligent consciousness,' he is mistaken in supposing that the absence of intelligent consciousness implies the complete absence of a conscious factor in the response.[2] Instincts and reflexes imply, then, the functioning of two distinct types of connate reaction patterns, both of which are to be distinguished from instinctive conduct which is never the functioning of a purely innate reaction pattern, although it is to a certain degree developed always from instincts.

II

The Range of Instinctive Conduct.—The distinction between instinctive conduct and instincts paves the way for the consideration of the large place which the former holds in human life. We have already suggested that most of our ordinary behavior is instinctive conduct, but this does not mean in any sense that complex actions such as we perform are the expressions of a few inborn impulses. Such a manner of thinking represents a vestige of scholastic simplicity which is genuinely subversive of all understanding of human behavior. What is meant is that even our very complex actions are in great measure conditioned by the instincts from which they have developed. To be sure, the simplest instinctive conduct is very largely the functioning of an innate reaction system, although conditioned by acquired factors. The proportion of innateness in the reaction pattern is measured by the directness of the connection between the stimulus and the response, or in other words by the character of the appreciation which the individual has of the meaning or significance of the stimulating object. In the simplest case the meaning of the object does not emerge as a striking factor in the act; it merely represents a modification in the response owing to a previous contact with the stimulating object. In a general way, we may very properly consider

[1] *Cf.* Stout, *Brit. J. of Psychol.*, 3, p. 244.

[2] Stout's separation of the conscious and movement components of a response clearly exemplifies the difference between his position and a functional viewpoint.

the simplest instinctive behavior as called out by the environment, and largely controlled by it, and not by the organism. As examples we may quote all those activities usually described by psychologists as subconscious or unconscious, which are very prominent in manual learning, and technical operations of all sorts.

On the other hand, the more complex instinctive conduct is more independent of the stimulating object and includes in its reaction systems a larger component of acquired factors. Here the meaning of the object serving as a definite foresight of the act, functions in a more precise manner, and in still more developed behavior includes an effective appreciation of the consequences of past responses to stimulating objects. The instinctive behavior at this stage may involve an elaborate series of memorial and thought functions, and when so complicated its specific characteristic as an instinctive behavior is the fact that it is perceptually stimulated, that is, the act is not initiated by a problematic situation. In this last class we may place all the involved social behavior which constitutes many of our daily responses. We must conclude, then, that instinctive conduct composes a considerable portion of practically all adjustments from the simplest to the most complex.

The Intelligence in Instinctive Behavior.—We may sum up the essential characteristics of instinctive behavior by pointing out the invariable presence in it of at least the rudiments of intelligence. Thus in many cases the reaction system, although a response to an immediately presented perceptual stimulus, is still carried out by predominantly acquired reaction factors, as is convincingly exemplified by much of our socially restricted behavior. Such acts are spontaneous responses to definite perceptual stimuli, but they are performed in roundabout ways and in many instances tend toward concealment. The openness and frankness with which such acts are originally performed are by virtue of social disapproval more or less successfully repressed.

Distinction of Instinctive from Rational Conduct.—The great variety and complexity of instinctive responses make

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it necessary to distinguish them from rational acts, a discrimination which is all the more pertinent when we consider that in the final analysis all of our acquired reaction systems are at some level integrations of elementary instinct acts. As a response to a problematic situation the rational act is probably always initiated by an indirect stimulating object through some highly developed meaning function. Unlike complex instinctive behavior the rational act is not only guided to its conclusion by intelligent functions, but is originated by a reflective consideration of ways and means. Thus it becomes the basis for all transformative conduct, that is, action which remakes the environmental conditions through some function of creative imagination, while in the case of instinctive conduct the result is usually merely an adaptation to those conditions.

III

The Specificity of Instincts.—Whether or not instincts are specific in their functioning is a crucial inquiry for the understanding of them, and a problem which may throw considerable light upon the distinction between instinctive behavior and instincts. It is important to note that since instincts are simple and immediate responses to specific stimuli which bring innate action systems into function, they presumably must be specific in their results.

This view, however, is not generally held by psychologists, although some adhere to it so tenaciously that the observation of the indeterminateness and indefiniteness of human behavior influences them to deny the existence of instincts in the human being. While it is entirely demonstrable that mature persons possess no instincts, this must not be interpreted to mean, as Stout does, that human behavior in general has no instinctive foundation in the form of concrete action patterns.[1] To believe in the absence of instincts in the human

[1] Our interpretation of Stout's position is in no wise invalidated by his reluctant inclination, expressed in the third edition of his 'Manual' (p. 360), to make the term instinct refer to general capacities, such as 'innately organized interest,' 'attention,' and 'power of learning by experience in certain directions.' On this basis he asserts that 'the whole development of human minds has its root in connate tendencies of this sort and is inexplicable apart from them.' From our standpoint in appears that Stout is here avoiding the essential problem of instincts.

individual because instinctive conduct is contrasted with intelligent conduct is to overlook entirely the facts (1) that we are studying concrete conscious behavior, and for that reason we need not think of an instinct as a permanent spring of action, the absence of which at the present time indicates that it was never present; and (2) that intelligent behavior is developed by the integration of simple types of action, a fact which enables us to understand how the reaction pattern of an instinct becomes elaborated and developed into a complex intelligent response.

An inquiry into the views entertained concerning the definiteness of instincts reveals the fact that what is frequently meant by an instinct is a neuro-muscular function. Thus Stout, for example, describes an instinct as a "purely biological adaptation comparable to the prearrangement of structure and function which in human beings subserves the digestion of food."[1] Upon examining this conception we are impressed with its inadequacy to represent human behavior, although we are in hearty agreement with Stout in rejecting such a view as that of Bergson-Carr, stated by Stout as the belief that there is a special form of psychical activity which requires the technical name of instinct.[2] We insist that not because human behavior has no instinctive basis do we not find instincts, but because the latter have become developed into intelligent behavior in the course of the individual's contact with his surrounding conditions. This fact Stout could have seen had he not been prevented by his general psychological standpoint from appreciating that the psychologist is interested in modes of response to stimuli, and not in expressions of mentality. Apparently, Stout assumes the specificity of instincts, and from such a premise he concludes that there are no instincts in the adult human being because he does not find man performing acts which express a mental process, through innately coördinated motor mechanisms.[3] Stout consequently fails to appreciate the

[1] *Brit. J. of Psychol.*, 3, 243.
[2] *Ibid.*
[3] *Cf.* McDougall, *Brit. J. of Psychol.*, 3, 269 ff.

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large place which instinctive conduct plays in the life of the human individual.

When we turn to the work of Thorndike,[1] who is attempting to investigate the 'original nature of man,' we find much to commend in his description of the specific instinct responses. Beginning with the admirable intention to describe concrete facts of behavior, he scouts the viewpoint which makes of instincts generalized tendencies to bring about some vague result presumed to be beneficial to the organism.[2] Thorndike stands upon firm scientific ground when he looks upon instincts as specific types of unlearned responses to definite kinds of stimulating situations, but his work presents us with grave difficulties. Conceived in neuro-biological terms, it implies that man's 'original nature' remains forever a prominent part of his behavior equipment. From this fact arise several implications tending to misconstrue the actual character of instinctive behavior.

In the first place, such a viewpoint cannot escape the implication that the human individual acts precisely as does the animal, since the former is fitted with a similar sort of neuro-muscular structure, and secondly, a more serious difficulty is that such a position leaves no room for the development of behavior.

The first difficulty must be understood as referring to the obvious faultiness of the attitude that human behavior is permanently like that of the lower animals. It is true that in the case of infants the acts are like those of the simpler organisms, but this is because we are observing simple instincts. In older children and adults the behavior has become integrated into intelligent conduct and is thus qualitatively different.

In answer to the possible reply of Thorndike that a sufficient differentiation of conduct in man and animals is allowed for by the combination of neural elements, we might suggest that such a way out of the difficulty would only result in describing complex abstractions instead of observable behavior. Human conduct is infinitely more complex in every

[1] *Educational Psychol.*, 1913, Vol. I.

[2] *Cf.* James ('Principles,' 1890, II., 183), whom Thorndike follows.

phase of adaptational character than can be accounted for on the basis of the combination of neural elements. Obviously the neural connections are essential mechanisms in all behavior, and since the activities of man are more complex than those of animals, these mechanisms must necessarily be more elaborate, but the nervous function cannot do anything more than mediate the spontaneous movements of the individual.[1] It is because the neural hypothesis was developed in connection with work on animal instincts that it has any significance as an explanatory principle, inasmuch as the animal instincts are very simple activities and so lacking in intelligence as to be almost mere biological functions.

We cannot agree with Drever,[2] who is essentially a follower of McDougall, in his criticism that the lack of differentiation in Thorndike's theory between human and animal instincts points to the nonspecificity of instincts. Drever insists[3] that there is no genuine specificity in Thorndike's instincts, since, for example, the 'instinct to escape from restraint' is so complex as to involve in the case of a little child 'stiffening, writhing, and throwing back the head and shoulders' and in the older child also 'kicking, pushing, slapping, scratching and biting.' Drever declares that the instincts mentioned belong with the six others enumerated by Thorndike[4] under McDougall's heading of pugnacity, and that the precise factor of unity is the accompanying emotion of anger. As a further argument against the specificity of instincts, Drever indicates that in some cases we cannot predict what a specific response will be, and the individual may try many different ones in succession. Thus, for example, under some conditions of stimulation the person may respond by flight or concealment, and in some cases by both reactions in turn.

[1] It is unfortunate that psychologists appear to overlook the fact that constructive biologists do not think in terms of isolated nerve functions, but in terms of neuro-musculo-glandular systems. In this connection it appears that if Thorndike has avoided 'mystic potencies' ('Educ. Psychol.,' p. 11) he has done so only by translating them into neural terms.

[2] 'Instinct in Man,' 1917, p. 155.

[3] *Op. cit.*, p. 166.

[4] *Op. cit.*, p. 68 ff.

The writer is satisfied that instead of proving the non-specificity of instincts, what Drever really shows is that human beings respond only by means of instinctive behavior and not with instincts. To repeat, instead of responding merely with an innately organized reaction system, the individual reacts with a complex acquired reaction pattern, which in the course of his development has had an increased knowledge and affective factor added to it. It is for this reason that the anger or fighting situation calls out such a wide and varying series of actions. In order to explain such conduct it is entirely unnecessary to invoke a dubious interpretation involving an unwarranted conception of the nature and function of the emotions as Drever following McDougall does.

Drever seems to realize that human behavior is a complex function developed in interaction with stimulating circumstances, when he writes that "behavior will be largely determined, first of all, by the circumstances of the case, by what kind of response will best secure safety. It will be determined, in the second place, by the intensity of the fear aroused, and two individuals may behave in two entirely different ways in response to the same situation, according to the degree of fear aroused."[1] This unimpeachable observation, which certainly controverts Thorndike's position that an instinct (instinctive behavior) is the functioning of a neuro-muscular apparatus, should have led Drever to see that the actions which he quotes from Thorndike's description are phases of intelligent instinctive conduct, and not the expressions of a mysterious 'general' instinct. Were Drever thinking in terms of concrete behavior he would easily see that instinctive conduct is not the functioning of an 'end,' or 'instinctive impulse' with an intelligence entity to carry it out,[2] but that it is a definite response to a stimulus which involves in its specific mode of action the integration of numerous previous experiences. In all cases of actual instinctive behavior the 'end' is gratuitously imposed upon

[1] *Op. cit.*, p. 163.
[2] *Ibid.*, p. 122 ff.

the situation.[1] What actually happens is that at any particular time certain combinations of surrounding circumstances stimulate the person to perform definite acts, provided that he has the necessary equipment of reaction systems. The adequate consideration of the stimulating auspices of behavior entirely removes the necessity of postulating teleological powers in the organism.

The spectator may profit by Drever's attack upon Thorndike's position by observing that on the one hand in his endeavor to avoid "mystic potencies" Thorndike refuses to interpret behavior as it actually occurs, preferring to lean upon unreal if not mystic potencies, while on the other, Drever,[2] following McDougall,[3] describes behavior in a more acceptable manner, but does not hesitate to explain it as the result of metapsychological agency.

The second difficulty with Thorndike's view of instincts, namely, that it disregards the development of behavior, may be considered as a derivation from the first difficulty. It results in the misinterpretation of human action, which as we have seen has as its primary characteristic the process of integration. A critical study of such behavior indicates conclusively that not a single act of an adult person[4] is an original response, but always a complex development of acquired reaction systems. It appears that Thorndike must think of instincts in the adult as drives or potencies of some sort, that is to say, at this point they have lost their specific character. In his failure to distinguish between instincts and instinctive conduct Thorndike vitiates his original excellent intention to describe actual psychological occurrences. Consequently, his interpretation leaves unfulfilled

[1] In this connection it is extremely edifying to observe the highly moral ends that are sometimes imposed upon the instincts, such as 'heavy and unremitting toil on behalf of the offspring' in the case of the parental instinct. *Cf.* McDougall, 'Soc. Psychol.,' 1916, p. 269.

[2] "Instinct is the 'life impulse' becoming conscious as determinate conscious impulse," *op. cit.*, p. 88.

[3] "For I hold that the instincts are essentially differentiations of the will to live that animates all organisms and whose operation in them makes the essential difference between their psychophysical activities and the physical processes of inorganic nature." *Brit. J. of Psychol.*, **3**, p. 258.

[4] Excluding the reflexes, of course.

his original functional promise, and ignores therefore one of the extremely important factors in conscious behavior, namely, the stimulating circumstances. In not allowing for an interpretation of the actual responses which an organism makes in adapting itself to surrounding conditions, Thorndike's position results in an inert structuralism which prolongs the intellectual tradition of a permanent self.[1]

The most zealous advocate of the non-specificity of instincts is probably McDougall who approaches the problem from the angle of social behavior. This author impugns the theory of social action which assumes 'that man is a reasonable being who always intelligently seeks his own good and is guided in all his activities by enlightened self-interest.'[2] Unfortunately McDougall's easy victory over such a vulnerable position has resulted in his substitution of another absolute spring of action as the basis for all human behavior, namely the series of instincts. The ubiquity and persistence of certain types of action no doubt has influenced him to propound the hypothesis that the human 'mind' is constituted by the sum of innate tendencies which bring about the specific actions of the individual. As will appear in the course of our discussion these tendencies McDougall believes to be permanent psychic entities. The assumption that instincts are the 'essential springs or motive powers of all thought and action' necessarily implies therefore that they are general capacities to bring about certain actions, for otherwise there would be required an infinite number to account for all the variety of social behavior.[3] The supposition of the non-specificity of instincts in turn creates a presumption in favor of the perseverance of dispositions as permanent tendencies of human actions.

An impartial investigation of behavior clearly demonstrates the extravagance of assigning any absolute foundation for human conduct. Thus for example, to insist upon instincts as the exclusive springs of action is to lose sight of

[1] As a series of physiological mechanisms.

[2] 'Soc. Psychol.,' p. 11.

[3] "Lightly to postulate an indefinite number and variety of human instincts is a cheap and easy way to solve psychological problems." 'Soc. Psychol.,' p. 26 ff.

the actual fact that many human actions are in a genuine sense rationally motived. As a consequence of seeking an absolute factor in human behavior, McDougall reaches the same result as Thorndike, namely, a form of abstractionism which adds little to the comprehension of such behavior.

The impuissance of McDougall's conception of instincts as an interpretation of conduct is instructively intimated in the existence of an uncrossable barrier between his exposition of instincts and his discussion of social behavior. Although he starts out with the assertion that an instinct is a psychophysical disposition, not only to act but also to perceive, attend, and feel, that is to say, a concrete action,[1] he really thinks of it as an enduring condition or faculty of some sort.[2] The hypostatic nature of McDougall's thinking appears in its most overt form in his protest against using the term instinct to denote an action.[3] There is apparently no way in which such instincts can develop into complex social behavior excepting by some form of crude mechanical agglomeration.

In all fairness to McDougall it must be said that he realizes the appalling chasm which separates his instincts from the complex behavior of the social type, for he develops a theory to account for the fact that instincts, while substantial elements, can still be the basis for all complex human action. This theory assumes that an instinct can be divided into 'three corresponding parts, whose activities are the cognitive, the affective and the conative features respectively of the total instinctive process.'[4] Now the emotional factor is assumed to be unmodified throughout all the various changes which involve the other two factors;[5] so that not only can you find the same dispositions in animals as in man, but in man they can develop to any possible degree. Unfortunately for McDougall this theory glaringly exposes his indefensible position. For note, he allows for so much development in

[1] 'Soc. Psychol.,' p. 26 ff.

[2] *Brit. J. of Psychol.*, 3, 253. It seems clear that McDougall does not hold that the enduring condition of an instinctive act is a definite potential reaction system, that is to say, a concrete response pattern which will function when stimulated.

[3] *Brit. J. of Psychol.*, 3, 253.

[4] 'Soc. Psychol.,' p. 32.

[5] *Ibid.*, p. 34.

the dispositions that he almost gives up the idea that the springs of human actions are innate. In extricating himself from this difficulty McDougall further weakens his position, since in making the emotional aspect of the instinct the sole innate spring of action he runs counter to the fact which he himself admits,[1] namely, his inability to point out definite actual emotions in any but the 'principal' powerful instincts. The precariousness of McDougall's position is not at all mitigated by his highly questionable identification of the affective component of an instinct with an emotion.[2]

The conclusion that we may draw from the imperfection of McDougall's view is that he does not fully realize that he is attempting to interpret instinctive conduct, which is an entirely different matter from demonstrating the function of instincts in all the complex actions of human beings. He therefore starts from the wrong premises and is easily led to the bizarre idea of the substantial mental character of instincts. It is an egregious error for McDougall[3] to think that he is alone in believing that instincts are at the foundation of our mental life. It is almost a universal conviction among psychologists that all human behavior is based upon instincts as a foundation, but the important point is, that this foundation as an actual phenomenon is only a transitory phase of a maturation process.[4] For instance, when we observe the fighting reactions in the child and in the adult we are severely impressed with the qualitative difference of the respective reactions. In the first place, the specific responses in each case are different, implying that no enduring nervous basis can be inherited for the purpose.[5] Again, the stimulating situations may be absolutely different not only in the developing individual at different stages, but also in the same stage of growth at different moments, and in different individuals at the same moment. Not only will a fear situation in any of these cases call out different sorts of

[1] *Ibid.*, p. 46.

[2] *Cf.* Drever, *op. cit.*, p. 156 ff.

[3] *Brit. J. of Psychol.*, 3, 260.

[4] In the same sense as the fœtal structure which is the foundation for the adult physique is integrated in the course of development.

[5] *Cf.* 'Soc. Psychol.,' p. 29.

responses in the individual, but it may call out the same sort as an anger situation. In all cases the response of the individual will depend in part upon the multiplicity of circumstances immediately surrounding him. The fighting reactions, for example, will depend upon the presence or absence of onlookers and the regard one has for them if they are present, as well as upon the thing at stake in the contest. Such reaction will also be conditioned by all sorts of technical information and convictions one has acquired relative to fighting in general or to fighting under these specific circumstances. When we observe a complex social action we are convinced that even such elaborate and significant suggestions[1] which the penetrating students of human conduct enumerate, cannot fully cover its conditioning influences, although of course for some definite purposes not all of these influences are relevant.

McDougall's discussion involves the gratuitous assumption that the substantial instinct entity can be aroused under very different kinds of circumstances. For instance, at one time the instinct can be aroused by a natural stimulus and at another by a complex social situation, all through the medium of an emotion entity. There is apparently more than a smack[2] of the old faculty psychology in McDougall's thinking, a fact which is genuinely surprising when we consider that at certain points he almost realizes the distinction between instincts and instinctive behavior, as for example, in differentiating between the specific and general tendencies.[3]

McDougall's insistence upon the generality of instincts is based therefore upon the dubious premise that there are a few innate springs of all human conduct, rather than upon the observation that human behavior is a complex interaction of an experienced and intelligent person with a multiplex environmental situation. It is the very complexity of the total situation that seems favorable to the arbitrary analysis of it into a few constant factors. This is familiarly illustrated in the case of the complicated social and institu-

[1] Such as are found in Veblen, 'The Leisure Class,' etc.

[2] *Cf.* Drever, *op. cit.*, p. 16.

[3] 'Soc. Psychol.,' p. 20.

tional circumstances which are reduced to a few simple activities of the 'economic man.' McDougall[1] has gone only a step farther than Cousin, whom he severely criticizes, in the interpretation of the conditions of human activity, because the former fails to see that the dispositions to human action are all complex acquired functions and not a compound system of original sensori-motor arcs,[2] plus some type of antecedently functioning mental activity.[3] The explanation of McDougall's doctrine of generalized instincts seems to be the fact that he stands for a theory of psychological predestination,[4] and so he makes of the human individual a machine fitted with definite powers which require only an indifferent stimulus to make them perform whatever seems necessary to be done.[5] Although he condemns the practice in others, McDougall ascribes to the functioning of an instinct any frequent or constant form of action. Thus, the acquisition and building up of large estates are attributed to the acquisitive instinct.[6] It is a queer doctrine of magical potencies which can describe the development of such elaborate institutions[7] as we have in our complex life to the functioning of a dozen or so of instincts. And more anomalous still is the presentation of such a doctrine in face of the overwhelming facts pointing to the shaping of our instinctive behavior, by the lives and acts of persons and institutions.[8]

The entire controversy concerning the specificity of instincts is made possible only by an inclination toward a structural psychological position. When we take concrete

[1] *Ibid.*, p. 12 ff.

[2] 'Soc. Psychol.,' p. 29.

[3] Conative tendency—*cf. Brit. J. of Psychol.*, p. 261 ff. "The instinctive impulses determine the ends of all activities and supply the driving power by which all mental activities are sustained." 'Soc. Psychol.,' p. 44.

[4] "I hold to the reality of teleological determination of human and animal behavior." 'Soc. Psychol.,' Preface, second edition.

[5] The writer wonders whether McDougall considers the instincts as such absolute springs of action that they function either as determining the ends of all actions or merely by being suppressed. *Cf.* McDougall's discussion of the parental instincts, 'Soc. Psychol.,' p. 267 ff.

[6] *Cf.* 'Soc. Psychol.,' p. 323.

[7] "These impulses are the mental forces that maintain and shape all the life of individuals and societies." 'Soc. Psychol.," p. 44.

[8] *Cf.* Woodworth, 'Dynamic Psychol.,' p. 72 ff.

human behavior to be the province of psychology we are very soon impressed with the fact that instincts are necessarily specific in their functioning, but that the adult individual has no instincts. Furthermore, the obvious generality and unpredictability of adult behavior should lead us to observe that instinctive conduct is general because the environing conditions to which it is responsive are incessantly variable in their stimulating capacities.

IV

Relation of Instincts and Emotion.—The study of instinctive conduct has in recent years resulted in the almost universal agreement of psychologists that a very close relation exists between such behavior and emotions, although there are several doctrines as to the precise details of this relationship. It is held, on the one hand, that emotions are of instinctive origin and occur when the instincts are checked or in conflict, while on the other, it is believed that emotions are the correlates of instincts in some form. It must be granted that both these views are based upon observable conduct, and especially the fact that in many cases of instinctive behavior a powerful feeling element is involved; the importance of the data, however, intensified by the lack of uniformity in interpretation, demands a more adequate analysis.

The view that emotions are correlates of instincts is ably championed by McDougall, who, as we have seen, believes that the primary emotion is the affective element of the instinct. The primary objection to such an interpretation, as we have also seen, is that many instinctive actions do not involve emotions,[1] and that many emotional situations do not have such instinctive associates as are so convincingly discussed in the cases of anger and fear. As we have remarked above, the insistence upon the invariable presence of an emotion in every instinctive act is to reduce emotions in many cases to simple affective states.[2] It is significant that Drever, who closely follows McDougall, is forced to the

[1] *Cf.* Shand, 'The Foundation of Character,' p. 6, 370.

[2] *Cf.* Drever, *op. cit.*, p. 155 ff.

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conclusion that only some instincts have emotional accompaniments.

The conflict theory, insofar as it insists upon a conflict situation as the basis of an emotional behavior, meets with few if any exceptions in fact, but the question arises whether the conflict is in all cases a conflict of instincts. The critical analysis of the emotional situation indicates that this is not true. Before proceeding to such an analysis of emotional behavior it is well to describe its chief characteristics.

An emotion is an interrupting form of response to a suddenly presented stimulus in which various organic processes are put into function, which in turn facilitate the immediate performance of a new act. Among the outstanding features of an emotional action are the confusion and excitement which pave the way for a new act by inhibiting the behavior which is taking place when the emotion-exciting stimulus is presented. Naturally such an act is replete with affective and organic resonance, and here we find the clue to the relationship between the emotional and the instinctive types of behavior.

What happens in the case of the emotional situation is that a dissociation of the reaction systems of the person takes place; so that in the most violent type of emotion the person is left only with the capacity to act with almost purely physiological (reflex) behavior. From this extreme case we find a gradation of emotional conduct in which the disorganization leaves free to function a series of reaction patterns ranging from the simplest to the most complex instinctive behavior. The fear and anger situations offer excellent examples of the disturbances of behavior which leave comparatively simple forms of instinctive response to adapt the individual. A person may be walking along through a wood, perhaps thinking over some problem, when suddenly there is a cessation of the thought activity and the person finds himself in a state of great excitement and unpleasantness, and in readiness to run from a tiny creature madly scurrying through the brush. In this illustration, the simple instinctive, danger-avoiding response might appear, as the

most serviceable form of behavior under the circumstances. We see, therefore, that not because an emotion is a component of an instinct or a conflict between instincts is it closely related to instinctive behavior, but because under certain conditions of stimulation the reaction systems are so disorganized as to leave only some instinctive mode of behavior to function.

Upon the basis of such an interpretation we can understand the more refined emotional responses, namely, those in which no violent instinctive reaction is involved. In the functioning of the more subtle emotions[1] the environmental circumstances are such as to disturb only the most elaborate and definitely focused acquired reaction systems, for example, rational conduct, and thus leaves free to function such complex forms of behavior as almost entirely to dispel the appearance of a shock or conflict. The resumed activities in such cases are of course only slightly different from those interrupted.

V

In conclusion we might point out three cognate obstructive tendencies, which persistently hinder psychological thinking concerning instincts, and which prevent the scientific interpretation of instinctive behavior, namely (1) metapsychological speculation, (2) biological abstractionism, and (3) psychological simplification.

Metapsychological Speculation.—This motive has always been a prominent factor in discussions of instincts, and strangely enough is still responsible for the many inaccuracies and trivialities of those studies. The unmistakable theological implication of this attitude is manifested by the explanation of instinctive behavior in terms of a mysterious original force implanted in animals to carry out some primary end of life, as for example, the preservation of the species.[2] We have already had occasion to refer to the hardly less objectionable aspect of the metapsychological view, which makes

[1] Not the diffused feelings.

[2] Represented in psychology today by McDougall and Drever, who stand in the von Hartmann-Bergson line of development, *cf.* Drever, *op. cit.*, p. 89.

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instinctive behavior stand for everything that is considered unknown or persistent in conscious behavior.[1]

Much the worst disservice of the metapsychological attitude is precisely that it maintains unknowables which prevent the adequate investigation of psychological phenomena. To assume that instincts are ultimates of animal nature and to seek to describe these putative elements, precludes the conception of instincts as definite forms of concrete responses.

Biological Abstractionism.—We may consider the historical rise of biological abstractionism as a protest against the extreme vagaries of the speculative psychologists. The biological influences in psychology transformed instincts into simple psychological phenomena explicable in terms of the nervous structure of the organism. Thus we find the statement that the instinctive factors in behavior 'depend entirely on how the nervous system has been built up through heredity under the mode of racial preparation which we call evolution.'[2] Instincts are consequently considered to be specific arrangements of neural mechanisms; so that James, following Spencer, spoke of them as conforming to the general reflex type.

An unacceptable issue of physiological abstructionism is the tendency to overlook actual phenomena to such a degree as to allow for no difference between such widely varying behavior as we find in man and animals. Our study of instinctive conduct has afforded sufficient intimation that much of the unsatisfactory interpretation of such behavior can be traced directly to the fact that it is the animal type of reaction that is uncritically employed as an exclusive basis of description. As a consequence this comparatively simple behavior is resolved into hypothetical neural elements which can in no way account for so conspicuous a variation as the rapid development of human instincts into intelligent conduct, and the practically stationary condition of the

[1] So that the success of a politician or business man is attributed to the presence of political or business instincts, the desire of a nation to govern itself to the functioning of a self-governing instinct, and the building of cities to the presence of a gregarious instinct.

[2] Morgan, *Brit. J. of Psychol.*, **3**., p. 220.

animal instincts. It is small wonder, then, that the upholders of the physiological view fail to observe that the human individual merely passes through the stage of animal conduct just as he passes through the stage of simpler structural developments, and that the mature person is equipped with an entirely different series of reaction patterns than the animal or child. And so we find that, contrary to our expectation, the fact that the complete absence of instincts in the human individual forces us to resort to animal behavior in order to study them, does not influence the biological abstractionist to reflect upon the differences in the two kinds of behavior, but instead he is led to interpret human conduct in the same abstract terms as the simpler kinds of behavior. Incidentally, the failure to distinguish between the instinctive conduct of man and the instincts of animals results in the ascription of a degree of intelligence to animal conduct which is really not found there.

Probably the most serious defect of biological abstractionism is that it obscures the extremely dynamic character of human behavior. The principle of rigid neural functions is entirely inapplicable to the spontaneous and developmental aspects of our conduct, and favors the neglect of the stimulating circumstances which greatly modify it.

Psychological Simplification.—The unfortunate phase of the protest against biological abstractionism is the psychological simplification of human behavior, which reduces instinctive conduct to the functioning of psychical dispositions or impulses. As represented by McDougall and his followers, this view stands as a justifiable criticism of physiological abstractionism, but in its espousal of the subjective position as over against the objective, that is to say, the position of action and behavior,[1] it is hindered from interpreting instinctive conduct as it actually functions. Psychologists who are influenced by this viewpoint are unable to depart from a structural or content description of human behavior; they are prevented from conceiving of the complex non-rational conduct of man as the product of an intricate give and take

[1] *Cf.* Drever, *op. cit.*, p. 16.

process between persons and the social institutions which constitute their *milieu*. When such complex behavior is interpreted as an empirical consequent of numerous human conditions, we can readily see that religious conduct[1] cannot be 'a very complex and diversified product of the coöperation of several instincts,' that is to say, a 'compound' of simpler emotions. To describe religious behavior as the manifestation of a complication of simple mental elements is to forego the scientific advantage of observing the ramified interaction of persons with their surrounding political, economic and cultural institutions. The unwarranted simplification of human behavior means that instead of analyzing the social process in which are developed the deep-seated action patterns, the latter are gratuitously assumed as permanent elements of human character. The situation is not at all improved by asserting that complex 'impulses' are developed from simple 'impulses.'[2] To deny that instinctive conduct is socially formed reaction systems is to revert to the simplicity of the rustic who protests against the daylight-saving law as an interference with God's time.

A functional viewpoint of behavior, we submit, avoids completely the three insidious tendencies which we have just examined. Since the functional psychologist assumes the data of psychology to be concrete adaptational responses to surrounding things, he can whole heartedly reject all putative powers and elements, and confine his labors to the analysis of verifiable materials, such as human reaction systems are. Abiding by such a policy, a psychologist is *ipso facto* barred from an impatient out of hand solution of difficult problems. Especially in the matter of instinctive conduct, a functional viewpoint may lead to a scientific and significant, if tentative interpretation of an important series of psychological adaptations.

[1] Or religious emotion, *cf.* McDougall, 'Soc. Psychol.,' pp. 81–82, 89.

[2] "If we accept the doctrine of the evolution of man from animal forms, we are compelled to seek the origin of religious emotions and impulses in instincts that are not specifically religious."—McDougall, 'Soc. Psychol.,' p. 89.

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IMMOBILITY: AN INQUIRY INTO THE MECHANISM OF THE FEAR REACTION

BY J. P. M'GONIGAL

Judging by the uncritical spirit in which psychologists have received recent physiological conceptions, it would seem that the long discussion of emotion precipitated by the James-Lange theory had exhausted the interest of the psychologists about the time that it secured the attention of the physiologists. The current conception of fear is a case in point. To Darwin, Ribot, Mantegazza, Mosso, Lange and others fear, with its dual impulses of flight and immobility, was the most baffling of the major emotions. Today one finds it generally spoken of as a complex of the impulses of flight and attack, the once perplexing impulse of immobility receiving scant, if any, attention. This shift in opinion is traceable to the demonstrations of the physiologists that under the influence of either fear or rage the organism undergoes profound physiological modifications which prepare the body for sustained motor activity.

Now, it is not the business of physiologists to analyze subjective states and psychologists have no right to quarrel with such expressions as "the animal was either frightened or enraged." If they were not prepared for such inexactness in matters of importance to them, the very tone of the physiological literature should have warned them. The physiologists have been, very properly, absorbed in tracing the interrelations of certain obscure mechanisms which produce, among many other intricate effects, emotional reactions, the particular *kind* of emotion being of secondary interest. Not so the psychologist. To him, fear neither looks nor feels like rage. Fear is a more primitive reaction, it appears earlier in the life of the human infant, it is more uniform and definite in its manifestations, less adaptive and more widely distributed throughout the animal kingdom. Such being the

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case, it would be strange, indeed, if the mechanism of fear were not sharply differentiated from that of anger. In the present paper the attempt is made to define the physiological basis of fear, to show that it is distinct from that of anger and to vindicate the earlier psychologists in their belief that the fundamental impulse in the emotion is that of immobility.

For the purposes of comparative study we shall define fear as the typical reaction to situations of imminent or potential danger. Tracing this danger reaction downward from man to the lower orders, it will be found that the impulse to hide, crouch down, stand still, etc., becomes more and more pronounced until, in some insects, we reach the trance-like state of the death feint. The term 'death feint' is not only inaccurate but is used with misleading looseness to cover both the tetany of the lower orders and the remarkable state of relaxation seen in birds and animals. The reaction is, of course, not a feint at all. There is seldom any resemblance between the postures of a feigning animal and one really dead, while the implication of a purpose to deceive is obviously absurd. The reaction is, in fact, one of the least adaptive and most difficult to account for teleologically in the whole range of behavior. In the first place, the strength and duration of the response bears no relation to the stimulus. In some insects the slightest stimulus will cause a profound feint which cannot, thereafter, be produced by stimuli of any strength. In other species the insect can be made to feign as many as fifty times in succession, the duration of the feints increasing for the first few times and then rapidly decreasing, the stimuli being uniform throughout the experiment. The distribution of the reaction among the species is as erratic as its character. In closely allied forms, one will possess the reaction and others will not. This last observation applies also to the relaxed form of the feint found in birds and the higher animals. *Some* species of *all* orders possess the characteristic, but it must, on the whole, be considered an exceptional manifestation. The very fact of this wide and erratic distribution would seem to indicate the existance of some mechanism common to all animals, which

under certain conditions assumes the form of the death feint, but which in most cases, we must suppose, functions in some less conspicuous way.

The possibility of such a hidden existence of the mechanism is shown by an experiment of Holmes. In the lower orders, contact stimuli very generally cause reversal of tropisms. Holmes found this to be true of *Ranatra when in the water*. On land, however, the same stimulus produced the death feint, upon revival from which the insect showed the usual reversal.[1] In its customary environment there would have been no reason to suppose that *Ranatra* possessed the ability to feign. That a similar mechanism may, in this way, lie hidden behind the simple hesitancy of the startled individual of the higher orders is at least suggested by the gradation of the response in birds. Chicks, ducklings and plovers will, upon being startled, crouch down, pheasants stop dead and hold rigidly the posture in which they happened to be at the moment of fright; terns, peewits, land- and water-rail are 'feigners' that lie limp and allow themselves to be handled without showing signs of life. We shall assume, then, for the time being, that an unitary principle runs through all the various forms of danger response and proceed to take advantage of the opportunity afforded by its extreme expression in the death feint to study its mechanism.

As it appears in the lower orders, the death feint is not a state of mere quiescence. The muscular tension is often tremendous. A feigning *Ranatra* may be held horizontally by one of its slender legs, the whole weight of its body being sustained by the tiny muscles. Here, clearly, is a sharp redirection of nervous energy, which, since the posture may be retained for long periods, must depend upon some profound modification of the physiological state. Evidence of the same nature is given by Holmes, Towle, Yerkes, Parker and the Severins who have observed that upon revival the feigning insects show reversal of tropisms, indicating a change in sensitivity difficult to account for if the primary reaction is a mere reflex. Pointing in the same physiological direc-

[1] Holmes: 'Studies in Animal Behavior,' p. 104.

tion are the results of the Severins on the duration of successive feints in *Belostoma*. In a group of ten insects the average duration of the first thirteen feints were as follows: (time in minutes) 15.0, 32.4, 37.2, 24.0, 16.0, 15.9, 19.5, 12.8, 15.0, 9.1, 9.1, 5.4, 5.5. Specimen *A* of this group was made to feign fifty times for a total of 382 minutes, of which 256 were accounted for by the first ten feints. This distribution of time is typical.[1] Graphs of the feints of specially good feigners (made by the present writer) all show sharp peaks at the beginning and then a slow decline with a rhythmic tendency, the whole picture suggesting a reaction conditioned by some autocoid of which the supply is limited as in the case of adrenin. A similar suggestion is supplied by the reaction in birds. Lloyd Morgan mentions a water-rail that changed in an instant from a state of complete inanimation to the most violent and frenzied rushing about, while Holmes makes the same observation in regard to terns. Holmes could never get the birds to feign a second time. Remembering that the passage from the feint to the frantic struggles and blind flight occurs spontaneously and without any transitional stage, it would appear that the second state resulted from the exhaustion of some form of energy which served to maintain the first.

These various conjectures (of which we have no definite confirmation) that the death feint is the result of an unusual functioning of a mechanism common to all animals, and that it is due to the redirection of energy caused by some specific agent of the nature of an autocoid, are given support by the fact that under certain abnormal conditions a reaction strikingly similar, even in details, can be observed in the higher animals and man. This is the tetanic state produced by strychnine poison and tetanus toxin. Under the influence of these poisons the body becomes tense and rigid, the paroxisms, which are most easily induced by some form of contact, lasting, in man, usually about fifteen seconds. Two theories are advanced to explain the action of the poisons.

[1] Severin, Henry H. P., and Severin, Harry C.: 'An Experimental Study of the Death-Feigning of *Belostoma* (*-Zaitha* Aucct.) *flumineum* Say and *Nepa apiculata* Uhler,' Behavior Monographs, No. 3, p. 11.

The first states that the toxin increases the conductivity of the nerves to such an extent that coördinated activity becomes impossible, the chaos of currents resulting in tetanic rigidity of the muscles. The second theory, that of Sherrington, maintains that the reciprocal inhibitions normally maintained by the central nervous mechanisms are changed by the poisons to excitations. By using carefully graded doses of strychnine Sherrington was able to produce a state in which reflex relaxation was diminished and not replaced by excitation. "This phenomenon," he says, "shows well how little competent is the view of lowered spinal resistance to really explain the action of strychnine, for at this stage the stimulated arc that normally acts on the extensor muscle by inhibition is less able to affect it than before, so that on the spinal resistance view the resistance at this stage is actually heightened."[1] Sherrington's theory, in other words, attributes this pathological 'immobility' in the higher forms to a *redirection* of nervous energy analogous to that which the general nature of the reaction and the fact that it is accompanied by the reversal of tropisms, led us to assume in regard to the lower orders. Now, while the use of inducted poisons is a legitimate method of uncovering the mechanism of immobility, we have, fortunately, a more direct avenue of approach through the disorder of tetany, a disturbance similar to tetanus but milder in form. Tetany is exhibited in many diseases and is now generally believed to be of parathyroid origin. This view is based upon the undisputed fact that deprivation of the parathyroids produces tetany and that administration of parathyroid extract relieves the disorder. Schafer, who represents the later work on the endocrine organs, believes that this may be explained by the cholonic or restraining action of the parathyroid secretion which offsets in the normal animal the action of an autocoid of opposite tendency produced by the thyroid (thyrine).[2] Here we have an autocoid which, by redirecting the normal flow of nervous energy, produces a state of rigidity

[1] Sherrington: 'Integrative Action of the Nervous System,' p. 108; *vide* p. 106–13, 292–7.

[2] Schafer: 'The Endocrine Organs,' pp. 23 and 40.

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and muscular tension that precisely duplicates the conditions (known and surmised) of the typical death feint of the lower orders.

In the healthy organism, of course, the existence of this mechanism of immobility is concealed by the action of the parathyroids. Is it merely concealed? It might be suggested that the action we have just described is totally abolished in the normal individual and plays no part in the danger response of the higher orders. Yet, undoubtedly, animals and men are occasionally 'paralyzed with fear' and a comparison of the readily recognizable 'expressions' of fear and the known effects of thyrine will show that in the less violent

EXPRESSIONS OF FEAR[1]

(Expressions due to the skeletal musculature are omitted)

Quickened heart beat	Thyrine
Arrested respiration	Thyrine
Pallor	Adrenin
Perspiration	Thyrine
Immobility	Thyrine
Tremors	Thyrine
Dry mouth	Thyrine
Arrest of menstruation	Thyrine[2]
Arrest of lactation	Thyrine[2]
Protruding eyeballs	Thyrine[3]
Dilated pupils	Thyrine[3]

[1] Authorities: For expressions of the emotions—Darwin: 'Expressions of the Emotions in Man and Animals;' Ribot: 'The Psychology of the Emotions.' For effects of the autocoids—Biedl: 'The Internal Secretory Organs;' Schafer: 'The Endocrine Organs;' Gley: 'The Internal Secretions;' Cannon: 'Bodily Changes in Pain, Hunger, Fear and Rage;' Crile: 'Man—An Adaptive Mechanism.'

[2] While there is very little known in regard to these points there is an undoubted connection between the thyroid and the phenomena of lactation and menstruation. Ott and Scott state that iodothyrine inhibits lactation while Hertoghe claims the exact opposite. (Bell: 'The Sex Complex,' p. 89.) During menstruation there seems to be evidence of thyroid deficiency, since psychic disorders due to the disturbance are relieved by the administration of thyroid extract. Biedl believes that the tetany sometimes associated with menstruation, lactation and pregnancy is due to metabolic disturbances set up by the functioning of the female organs. (Biedl: 'The Internal Secretory Organs,' p. 44.) The arresting of menstruation in fear may possibly be due to the diversion of the thyrine from the genital organs. This, however, is pure conjecture. Ott and Scott also claim that adrenin inhibits lactation. I know of no record of any effect of adrenin in delaying or promoting menstruation.

[3] Also characteristic of adrenin but in a less degree. These are the most marked and distressing features of exophthalmic goiter, a disease of hyperthyroidism.

forms of the emotion there is clear evidence of thyroid activity. In making this comparison we should be on the lookout for manifestations of adrenal activity, for it is to these glands that current theory ascribes the organic basis of both fear and anger.

The chain of evidence seems complete. Starting with the death feint as an exceptional primitive form of the fear reaction, we were able to discover traces of a similar mechanism through the various orders up to man. In man our material pointed to the identity of this mechanism with the thyroid. Then by a comparison of the known expressions of fear and the known effects of thyrine we were able to show that the thyroid plays an overwhelming part in the production of the emotion, and, since the unrestrained functioning of the thyroid produces a state of complete immobility, it follows that the fundamental 'impulse' of the emotion must partake of this character. To complete our argument for a specific organic complex we shall proceed to a similar comparsion of the expressions and autocoids observed in anger.

EXPRESSIONS OF ANGER

Flushed face	Thyrine
Deep respiration	Adrenin
Muscular contraction	Adrenin
Salivation	Adrenin

It is significant that the visceral expressions of anger are meager as compared with those of fear. Ribot says, "Anger and fear form an antithesis, but the former has, both physiologically and psychologically, a more complex character."[1] Darwin makes a similar assertion and later observers have been baffled by the paucity of the expressions of anger. The effects of adrenin betray a similar complexity. On the whole, it is accurate to say that adrenin speeds up the conversion of energy and prepares the organism for violent effort, increasing the contractibility of the muscles, immunizing against fatigue, promoting coagulation of the blood, etc. It places the body, as Cannon tersely puts it, "upon a war footing." It energizes and exhilarates, whereas thyrine depresses and disorganizes.

[1] Ribot: 'Psychology of the Emotions,' p. 220.

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It is true that in regard to the constriction and dilation of the facial vessels these tables show a contradiction. It is difficult to account for this, though Cannon has suggested that the effect may be due to a purely mechanical result of blood pressure.[1] However, it would not affect our argument if it were shown that there were even more crossing of effect than this. It is not contended that the immobility reaction wholly accounts for the affective state of fear in the higher orders. An impulse to flee is distinctly recognized and in flight the energizing qualities of adrenin would be of decided service. Under the circumstance the organic complexes of the two emotions are surprisingly clear cut.

[1] Cannon: 'Bodily Changes in Pain, Hunger, Fear and Rage,' p. 227.